PB-213 751

REPORT ON POLLUTION AFFECTING SHELLFISH HARVESTING IN GALVESTON BAY, TEXAS

National Field Investigations Center

Prepared for:

Environmental Protection Agency

March 1971

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ENVIRONMENTAL PROTECTION AGENCY
WATER QUALITY OFFICE

REPORT ON

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PREPARED BY

DIVISION OF FIELD INVESTIGATIONS - DENVER CENTER
AND
SOUTH CENTRAL REGION
DENVER, COLORADO • DALLAS, TEXAS

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I. INTRODUCTION

Water quality standards were adopted for Galveston Bay and its tributaries by the Texas Water Quality Board in June 1967 and accepted by the Secretary of the Interior on January 28, 1968 in accordance with the Federal Water Quality Act of 1965. Pollution of these waters is subject to the provisions of Section 10, Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et seq.). Section 10(a) of the Act provides that the pollution of navigable waters in or adjacent to any State, which endangers the health or welfare of any persons, shall be subject to abatement.

Section 10(d) of the Act further provides that a Federal-State conference shall be called whenever, on the basis of reports, surveys, or studies, there is reason to believe that substantial economic injury results from the inability to market shellfish or shellfish products in interstate commerce because of pollution of such waters, and because of action of Federal, State or local authorities.

This report summarizes presently available information pertaining to the quality of the Galveston Bay system; evaluates that information with respect to applicable standards, statutes, regulations, and criteria; and recommends a program which will lead to compliance with established water quality uses.

Specific objectives of the report are:

(1) To describe existing water quality in the Galveston Bay system.

(2) To summarize presently available information pertaining to sources of pollution.

(3) To evaluate the impact of present waste discharges on water quality and uses, and to assess compliance with established State and Federal regulations.

(4) To indicate the effect of projected water related development upon water quality in the Galveston Bay system.

Sources of information contained in this report include: the National Estuarine Pollution Study, FWQA; the Texas Water Quality Board; the Texas Parks and Wildlife Department; the Texas State Department of Health; the Texas Water Development Board; the Galveston Bay Study (a cooperative Federal-State-local study currently in progress), Texas A&M University and the U.S. Army Corps of Engineers. Limited field studies were also conducted by the Division of Field Investigations, Denver Center, WQO - EPA, to obtain additional data. The cooperation and contribution of the various State, local and private organizations are gratefully appreciated.

II. SUMMARY AND CONCLUSIONS

The area considered in this report includes all of Galveston Bay, Texas, and its major tributary streams and embayments.

Nearly half of Galveston Bay is presently closed for shellfish harvesting due to excessive bacteriological contamination and the proximity to sewage and industrial waste effluents. Total coliform concentrations at two locations in the approved area of Galveston Bay and one location in the approved area of West Bay exceed the applicable criteria of 230 organisms per 100 milliliters more than 10 percent of the time (Appendix B), based on monthly samples collected by the Galveston Bay Study during the 1968-69 and 1969-70 shellfish harvesting seasons.

Under the applicable standards for shellfish harvesting, sampling to determine approved and prohibited areas must be conducted under the most unfavorable hydrographic and pollution conditions. In Galveston Bay, the most unfavorable hydrographic and pollution conditions occur with northerly and northwesterly winds as well as precipitation. During the 1968-69 shellfish harvesting season, these conditions occurred about 40 percent of the time. On days when the most unfavorable hydrographic and pollution conditions occur, virtually the entire approved area in Galveston Bay, including the most productive reefs, have total coliform concentrations exceeding the required criteria. If sampling were regularly conducted under these conditions, nearly all of Galveston Bay would be closed to shellfish harvesting due to excessive bacteriological pollution.

The major source of bacteriological pollution to both open and closed areas for shellfish harvesting in Galveston Bay is the Houston Ship Channel. The Clear Lake area also contributed to excessive total coliform concentrations in the Bay. The City of Galveston area, while not affecting concentrations in approved areas, does discharge significant bacteriological pollution to the closed areas. There are localized influences of bacteriological pollution in West Bay approved areas from Chocolate Bayou and in Galveston Bay proper from Double Bayou.

Of the more than 215 million gallons per day (MGD) of domestic waste which are permitted by the Texas Water Quality Board to be discharged to Galveston Bay and its tributaries, about 110 MGD is raw, inadequately treated and/or unchlorinated. As of January 1971, the two largest sewage treatment plants of the City of Houston which discharge to the Ship Channel area, the Northside and Sims Bayou plants, account for 103 MGD of unchlorinated discharge. The effluent from each of these plants contained nearly 35,000,000 total coliform organisms per 100 milliliters during February 1969 sampling.

Oil and hydrocarbon residues were observed in oysters taken from both approved and prohibited areas of Galveston Bay, ranging from 23 parts per million (ppm) and 26 ppm in the approved area to 237 ppm in a prohibited area near the mouth of the Houston Ship

Channel. These hydrocarbons are not generated by the oysters themselves but derived from petroleum wastes. The concentrations observed in oysters taken from approved areas in Galveston Bay are from two to six times greater than concentrations in oysters from West Falmouth Bay, Massachusetts. The State of Massachusetts closed West Falmouth Harbor to shellfish harvesting, based on residues in oyster tissue ranging between 4.0 ppm and 12.0 ppm. Odor tests on Galveston Bay oysters showed unacceptable concentrations of odor-causing materials in all samples from both approved and prohibited harvesting areas. The intensity of odor became less as distance from the Houston Ship Channel increased. There is a health hazard, in addition to bacteriological pollution, associated with consumption of Galveston Bay oysters due to the presence of oil and hydrocarbon residues in excessive concentrations.

According to 1968 Texas Water Quality Board permits, there are 75 sources of petroleum refining or related industrial effluents in the Galveston Bay area. These effluents constitute a permitted discharge of nearly 423 MGD with a total of 1,144,000 pounds per day of chemical oxygen demand. The permits allow the discharge of more than 55,000 pounds per day of oil and grease from 81 sources, although this is in direct violation of Section 11-b of the Federal Water Pollution Control Act as amended. The Texas Water Quality Requirements specify that receiving waters shall be "substantially free" of oil. Seventy-four of these sources are located on the Houston Ship Channel, accounting for 98 percent of the total permitted discharge. The major industries permitted to discharge oil and grease are: Diamond Shamrock Corporation at Deer Park, U. S. Plywood-Champion Paper Company, Armco Steel Company, Atlantic Richfield Company, Humble Oil and Refining Company, Southland Paper Mills, Shell Chemical Company, and Crown Central Petroleum Company. These eight sources account for 86 percent of the permitted discharges.

It is estimated that 1,600 pounds per day of lead, 5,000 pounds per day of cadmium, 400 pounds per day of phenols, 7,900 pounds per day of zinc, 300 pounds per day of chromium and at least 1,000 pounds per day of cyanide are discharged, primarily to the Houston Ship Channel. Concentrations of these heavy metals and toxic compounds in the waters of Galveston Bay and the Houston Ship Channel range from 8.5 times greater than background in natural seawater for nickel, to 108,000 times greater than background for chromium. These concentrations indicate substantial contamination of the receiving waters by waste discharges. Concentrations of toxic compounds in the Houston Ship Channel are three times greater than levels which could be tolerated for normal algal growth. The known major dischargers of heavy metals contamination are Diamond Shamrock Company, Armco Steel Company, Olin Mathieson Corporation, Houston Northside sewage treatment plant, U. S. Plywood-Champion Paper Company, Humble Oil and Refining Company (Baytown), and Shell Chemical Company (Deer Park). These sources discharge more than

500 pounds per day as determined by sampling conducted by the Texas Water Quality Board in February 1969. Although the health hazard and specific numerical criteria associated with concentrations of heavy metals and toxic substances has not been established by the appropriate regulatory agencies, the Texas Water Quality Requirements prohibit acute or chronic toxicity to human, animal, or aquatic life.

Dissolved oxygen and biochemical oxygen demand (BOD) criteria established by the State of Texas for the Houston Ship Channel are almost continually violated due to the discharge of municipal and industrial wastes. Although the Texas Water Quality Board permits specify that 180,800 pounds per day of BOD may be discharged from municipal and industrial sources to the Houston Ship Channel, studies conducted in the Channel during 1968 and 1969 indicate that as much as 363,000 pounds per day of five-day BOD is the actual loading. The aggregate total of waste discharges to the Ship Channel is in substantial non-compliance with the Texas Water Quality Board permits.

The 1968 permits allow the discharge of 315,000 pounds per day of suspended solids to the Houston Ship Channel. Bottom material dredged from the Ship Channel contains substantial quantities of organic sludges, oil and other pollutants characteristic of wastes discharged to the Channel. About one-third of the BOD loading and one-half of the suspended solids discharged from waste sources settle out and are incorporated in the bottom sediments. These waste materials contribute a substantial portion of the sediments which must periodically be removed by dredging. The total project cost incurred by the U.S. Army Corps of Engineers for dredging the Houston Ship Channel in 1970 is $2,807,000. The disposal of this highly organic spoil may cause water quality problems through dispersion of pollutants and through exercise of oxygen demand from the volatile material contained.

The total permitted discharge of waste effluent to Galveston Bay and its tributaries is approximately 779 MGD which may contain 583,000 pounds per day of suspended solids, 270,000 pounds per day of BOD and 1,657,000 pounds per day of chemical oxygen demand (COD). Of this total, 92.6 percent of the suspended solids, 85.5 percent of the BOD and 92.8 percent of the COD are allocated to industrial sources. Industrial sources contribute about 72 percent of the total waste flow.

Of the 277 municipal and industrial waste sources having discharge permits in the Galveston Bay area, the waste treatment needs and status of 189 are not listed. Where needs are indicated, 40 sources provide inadequate or no treatment and no abatement, beyond engineering studies in a few instances, is in progress. Seventeen sources have treatment facilities in progress; 22 are said to be in compliance with permit requirements. Nine sources either provide adequate treatment or have no needs.

The City of Houston discharges wastes from 41 treatment plants, only eight of which have flows greater than 1 MGD. Harris County sewer districts discharge wastes from 27 sources, only one of which has a flow of 1 MGD. Galveston has three sources and Baytown has five. The multiplicity of waste treatment plants does not provide adequate operations to assure the best treatment of domestic sewage.

The development of an electrical power plant at Cedar Bayou by the Houston Lighting and Power Company will eventually require about 5,000 cubic feet per second (cfs) of cooling water. Some of the intake cooling water will consist of grossly polluted water from the lower reaches of the Houston Ship Channel. The heated water will be discharged to the relatively unpolluted Trinity Bay. Water temperature in a large portion of Trinity Bay will be raised above background. Trinity Bay is the major spawning area for commerical shrimp in Galveston Bay.

The present actual economic loss to the Galveston Bay area caused by inability to market shellfish due to pollution ranges between $86,000 and $258,000 annually at dockside. If excessive hydrocarbon or heavy metals concentrations in oysters and/or sampling under the most unfavorable hydrographic and pollution conditions, as required, caused the closure of all Galveston Bay to shellfish harvesting, the potential damage would be substantially greater. The final retail value of shellfish products is roughly four times the dockside value. The total actual damages caused by pollution affecting shellfish harvesting in Galveston Bay are between $359,000 and $1,045,000 annually.

Sewage and industrial wastes discharged to Galveston Bay and its tributaries are causing substantial economic injury resulting from the inability to market shellfish or shellfish products in interstate commerce. Accordingly, the pollution of these navigable waters is subject to abatement under the provisions of Section 10 of the Federal Water Pollution Control Act, as amended (33 U.S.C. 1151 et seq.).

III. RECOMMENDATIONS

To eliminate the health hazard associated with consumption of shellfish from the Galveston Bay system and to abate the existing pollution, it is recommended that:

1) Due to concentrations of oil and hydrocarbon residues in oysters taken from approved areas in Galveston Bay, the Texas State Department of Health, in cooperation with the Food and Drug Administration, ascertain the extent of health hazard incurred, and, if warranted, recommend closure of Galveston Bay to shellfish harvesting. Consideration be given to prohibition of all commercial fishing in Galveston Bay until it has been ascertained that the marine species taken from the Bay are suitable for human consumption

2) Sampling for determining bacteriological acceptability of areas for shellfish harvesting in Galveston Bay be conducted under the most unfavorable hydrographic and pollution conditions as required by applicable regulations. The most unfavorable hydrographic and pollution conditions occur with northerly and/or northwesterly winds during or following periods of precipitation.

3) Effective disinfection of all waste sources contributing bacteriological pollution to Galveston Bay be provided. A program of centralization and abandonment of small plants be undertaken to assure the best treatment for domestic sewage, with an implementation schedule to be submitted to the Conferees within three months of the date of the first session of the Galveston Bay Enforcement Conference.

4) A waste source survey be conducted on all sources of domestic and industrial waste permitted by the Texas Water Quality Board to discharge effluent to Galveston Bay and its tributaries. This survey should characterize and quantify specific compounds being discharged and include recommendations and scheduling of abatement measures. A characterization and scheduling of abatement for the 55 waste sources discharging more than 500,000 gallons per day be submitted to the Conferees within eight months of the date of the first session of the Galveston Bay Enforcement Conference. The Texas Water Quality Board permits be amended to reflect the recommendations of this waste source survey including the compliance schedule.

5) The Texas Water Quality Board permits be amended to immediately prohibit the discharge of oil and grease as well as toxic materials from all waste sources.

6) The additional costs incurred by the Corps of Engineers for dredging of the Houston Ship Channel and the effect on water quality due to disposal of the organic sludge be evaluated. Recommendations of this evaluation include an assessment of damages among the waste dischargers to the Channel and, location of suitable spoil disposal areas to minimize or eliminate deleterious effects on water quality.

7) The Houston Lighting and Power Company be required to abate the waste heat load to be discharged from the Cedar Bayou

plant to Trinity Bay such that the monthly mean of the maximum daily temperatures not be raised more than 4°F during the fall, winter and spring (September through May), or by more than 1.5°F during the summer (June through August) at the point of discharge. A cooling system incorporating recirculation and reuse be installed at the Cedar Bayou power plant. The Houston Lighting and Power Company also insure that no deleterious effects or impairment of water quality occur in Trinity Bay by reason of the use of a polluted source for cooling water.

8) A committee be appointed to make recommendations to the Secretary of Health, Education, and Welfare and the Administrator of the Environmental Protection Agency within one year from the date of establishment, on interim specific numerical criteria in both water and meat for acceptance of shellfish and other commercially valuable species taken from Galveston Bay. The specific numerical criteria to include bacteriological, oil and hydrocarbon residue, taste and odor, as well as other acute and chronically toxic or growth-inhibiting parameters. The committee include representatives of the Food and Drug Administration and the Environmental Protection Agency, in cooperation with appropriate Texas regulatory agencies.

9) Color of the waste effluent from U.S. Plywood-Champion Paper Company and Southland Paper Mills be reduced to natural background occurring in uncontaminated area waters.

10) An assessment be made of the total waste load which can be discharged to Galveston Bay and/or its tributaries to meet applicable State and Federal water quality standards as well as the recommendations of this report. This waste load be allocated among individual waste dischargers and not be exceeded regardless of future development.

IV. DESCRIPTION OF AREA

A. PHYSICAL DESCRIPTION

Galveston Bay is located in southeastern Texas on the Gulf of Mexico about 25 miles southeast of Houston, the largest city in the State. The Galveston Bay estuarine system, consisting of four large bays, Galveston, Trinity, East, and West Bays, and numerous smaller bays, creeks and bayous, has a total surface area of about 533 square miles and is the largest estuary on the Texas coast. The combined shoreline totals 245 miles.

The major bays are broad and shallow, averaging less than ten feet in depth. The smaller bays, creeks and bayous are shallow and sluggish. Marshes border the open water in many areas.

Most of the land surface adjacent to the bay system is only a few feet above sea level and is virtually flat for about 50 miles inland from the Gulf of Mexico. The natural drainage is poorly defined and has been altered by irrigation, drainage canals, and other man-made waterways.

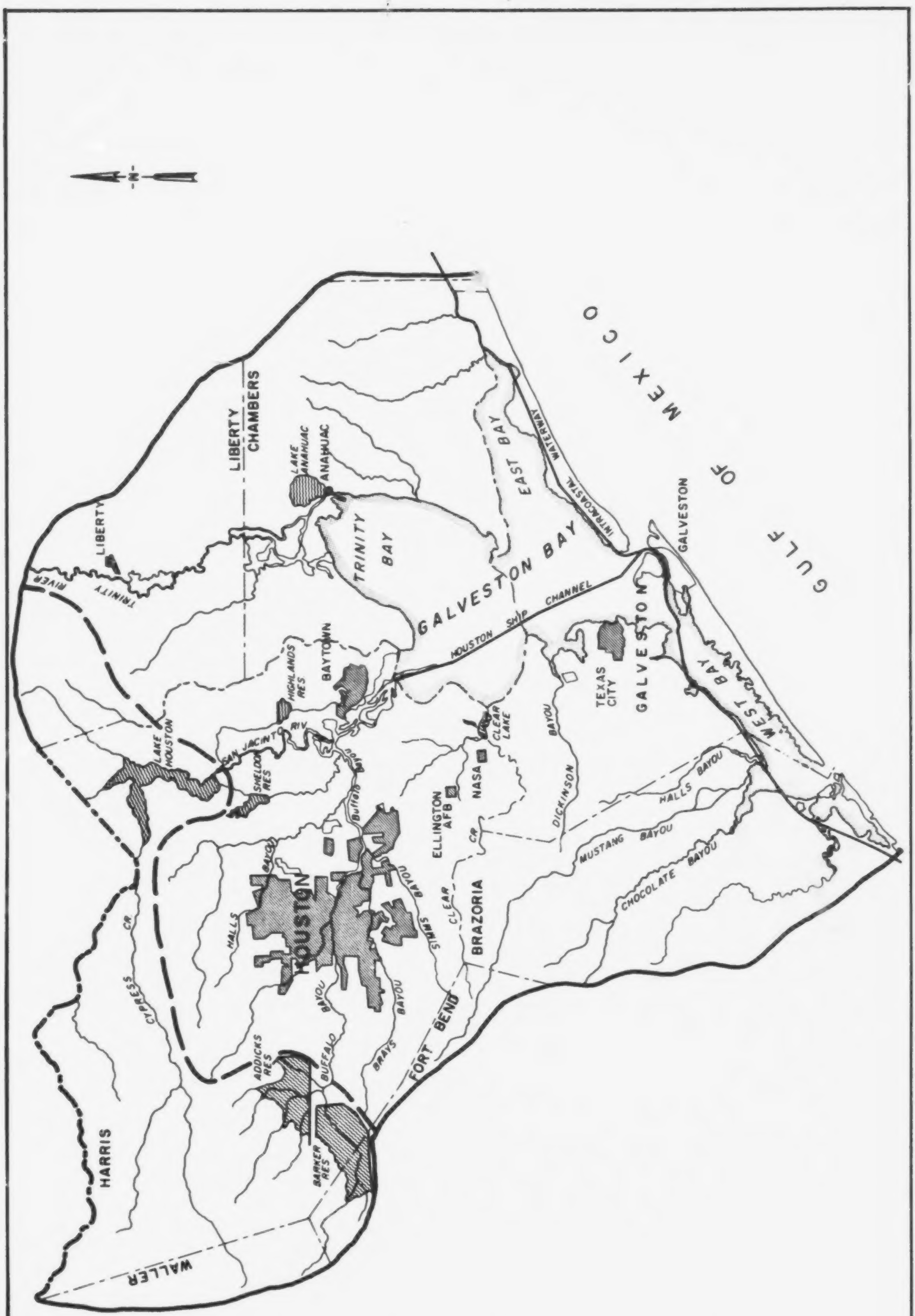
Impoundments on the Trinity and San Jacinto Rivers regulate fresh water inflows from these streams. As a result, the hydrology of the estuary is influenced primarily by inflows from an area of 3,600 square miles in the immediate vicinity. The area includes 600 square miles of the lower Trinity River Basin, 1,500 square miles of the lower San Jacinto River Basin, and 1,500 square miles which drain directly into the bay system through bayous and creeks. The total drainage area of Galveston Bay is 24,300 square miles of which 17,800 square miles is in the Trinity River system and 3,900 square miles in the San Jacinto system. The remaining 2,500 square miles is from numerous small streams draining to the bay.

Three major passages connect the estuary with the Gulf of Mexico. San Luis Pass and Rollover Pass, an artificial fish passage, are outlets for West and East Bays, respectively. The largest passage is Bolivar Roads, located between Galveston Island and Bolivar Peninsula. This openeing is the primary outlet for the estuarine system.

Several navigation channels are located in the estuary. Of major importance is the Houston Ship Channel, a dredged deep-draft channel which enters Bolivar Roads, traverses Galveston Bay, the San Jacinto River and Buffalo Bayou, and terminates in Houston about 50 miles from the Gulf of Mexico. Shorter deep-draft channels connect port facilities in Galveston and Texas City with the shallow-draft Intracoastal Waterway which traverses East and West Bays. Other shallow waterways connect various points in the estuary system. The area under consideration is illustrated in Figure IV-1.

B. CLIMATE

The average annual rainfall in the Houston area is approximately 45 inches per year, with monthly rainfall evenly distributed



N
GULF OF MEXICO
LIBERTY
CHAMBERS
LIBERTY
LAKE ANAHUAC
ANAHUAC
TRINITY RIVER
TRINITY BAY
EAST BAY
INTRACOASTAL WATERWAY
GALVESTON BAY
GALVESTON
HOUSTON SHIP CHANNEL
BAYTOWN
HIGHLANDS RES
LAKE HOUSTON
SAN JACINTO RIV
SHELDON RES
TEXAS CITY
GALVESTON
WEST BAY
CLEAR LAKE
NASA
ELLINGTON AFB
DICKINSON BAYOU
HALLS BAYOU
MUSTANG BAYOU
CHOCOLATE BAYOU
BRAZORIA
CLEAR CR.
SIMMS BAYOU
HOUSTON
HALLS BAYOU
BUFFALO BAYOU
BRAYS BAYOU
CYPRESS CR.
ADDICKS RES
BARKER RES
FORT BEND
HARRIS
WALLER

Figure IV-1 Galveston Bay Area 16b

throughout the year. Thunderstorms are the main source of precipitation, with rainfall of several inches per day not uncommon.

Temperatures are moderated by the influence of winds from the Gulf, which result in mild winters and warm humid summers. Average daily temperatures range from about 53°F in the winter to about 83°F in the summer, with an annual mean temperature of 69°F.

Prevailing winds are from the southeast and south, except in January, when frequent passages of high pressure areas bring prevailing northerly winds. Thundersqualls and tropical storms with high wind velocities occasionally pass through the area.

C. HYDROLOGY

Freshwater inflow to the estuarine system from the Trinity and San Jacinto Rivers and other coastal streams averages about 11,300 cubic feet per second (cfs), or an average annual volume of 8.2 million acre-feet. Both the rate of inflow and the annual runoff fluctuate widely. For example, in 1965 the average weekly inflow varied from less than 1,000 cfs to more than 45,000 cfs. Between 1941 and 1957, total annual inflow varied from less than 2 million acre-feet to more than 20 million acre-feet. Precipitation falling directly on the water surface of the estuary contributes a fresh water inflow of about 1.4 million acre-feet annually.

The location, relative magnitude and variability of the major sources of freshwater exert a strong influence on water quality in the estuarine system. The Trinity and San Jacinto Rivers together contribute almost 90 percent of total freshwater inflow. With an average annual flow rate of 7,900 cubic feet per second, the Trinity River strongly influences salinity levels in Trinity Bay. The Houston Ship Channel traverses the lower ten miles of the San Jacinto River. High flows in the river thus tend to flush degraded water from the middle reach of the ship channel out into Galveston Bay. Buffalo Bayou, a small stream with a drainage area of about 360 square miles, discharges into the upper end of the ship channel in the City of Houston. Peak flows in the bayou following heavy rainfall frequently flush the water contained in the upper 25 miles of the ship channel, into Galveston Bay.

A major portion of the water supply for municipal and industrial purposes in the Galveston Bay area is obtained from groundwater sources. The principal freshwater aquifer in the area is the Gulf Coast Aquifer which has a saturated depth exceeding 3,000 feet. Recharge of the aquifer is adequate to sustain the present rate of pumping if the withdrawal points were adequately dispersed. Sustained heavy withdrawals in local areas have caused overdrafts of the aquifer. Declining water tables, land subsidence and salinity intrusion problems have resulted. A reduction in ground water withdrawals is expected in the future as these problems become more severe and alternate surface supplies become available.

Two types of tides occur in the Galveston Bay estuary during normal weather. Diurnal tides, with an average range of 1.25 feet, exist during two to three weeks per month, and semi-diurnal tides, with an average range of 0.5 feet, prevail during the remaining period. The complex geometry of the bay causes amplifications and reflections of normal tidal effects resulting in considerable spatial variation in tides. During unusual weather conditions, such as high winds or the passage of a cold front, the Galveston Bay tides become wind-dominated and no consistent tidal performance can be observed.

Current measurements made by the Corps of Engineers show that ebb and flood currents in the Houston Ship Channel are about 1.5 feet per second[1/]. In shallow areas of Galveston Bay, water currents average between 0.3 and 0.4 feet per second. However, in some of the passes and channels between reefs, currents may range as high as four feet per second.

D. POPULATION

The population of the Galveston Bay Basin, including three counties and portions of four additional counties, was estimated at 1.4 million in 1960. By 1968, the population had increased to an estimated 1.8 million. The Houston Standard Metropolitan Statistical Area (SMSA), with 1970 population of 1.9 million, and the Galveston-Texas City SMSA, with combined 1970 population of 178,000, are the most important urban areas.

[1/] Bobb, W. H., and R. A. Boland, Jr., Galveston Bay Hurricane Surge Study, Technical Report H-69-12, July 1970, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

The population of the area is expected to continue the rapid growth rate of recent years. Projections indicate that the population of the area will triple by the year 2020.

E. ECONOMY

The economy of the area rests heavily on manufacturing, chiefly in the petrochemical field. Manufacturing is concentrated around the southern and western shores of Galveston Bay, in the Houston metropolitan area, and along the Houston Ship Channel. This concentration is expected to become more pronounced as the potential development of the area is realized.

Since construction of the Houston Ship Channel in 1914, Houston has become a major port, now surpassed in total tonnages handled by only two other U.S. ports, New York and New Orleans. The requirement for sites located near the Texas oil fields and major shipping lanes has led to intensive development along the Ship Channel of refineries, chemical and petrochemical manufacturing plants. Fertilizer factories, gypsum and cement plants, two steel mills, paper manufacturing and other industrial facilities are also located adjacent or in close proximity to the Ship Channel.

Location of the National Aeronautics and Space Administration's Manned Spacecraft Center near Clear Lake on Galveston Bay has attracted associated components of the aerospace industry to the Houston metropolitan area and has helped to diversify the economy.

The service industries and local, State, and Federal government are presently the largest employers in the area. This category of employment along with employment by the trade industries is projected to substantially increase in the future relative to employment in manufacturing and other categories.

F. WATER USE

A variety of beneficial uses is made of the waters of the Galveston Bay estuarine system and tributary streams. The most important of these uses include municipal and industrial water supply, propagation of fish and wildlife, navigation, recreation, and irrigation. The rapidly expanding electrical power requirements for the Galveston Bay area are being paralleled by increased use of water for cooling purposes.

Municipal and Industrial Water Supply

Water use for municipal and industrial purposes other than condenser cooling water was estimated in 1960 to total about 608,000 acre-feet per year (544 million gallons per day-MGD) for the Galveston Bay area. Almost 80 percent of this water supply was obtained from groundwater, as shown in Table IV-1. The relative use of water at various locations in the area is also shown in the table. It is estimated that average annual water use will total about 1.7 million acre-feet (1,520 MGD) by 1990 and 3.3 million acre-feet (2,850 MGD) by 2020.

In 1968, nine public utility steam electric generating plants were operating in the vicinity of Galveston Bay. These plants have a production capacity of 3,632 megawatts and a peak demand

TABLE IV-1

MUNICIPAL AND INDUSTRIAL USES OF WATER IN THE VICINITY OF GALVESTON BAY 1960, AND PROJECTED 1990 AND 2020

(1,000 acre-feet per year)

Basin	Zone	1960			Projected 1990			Projected 2020		
		Ground	Surface	Total	Ground	Surface	Total	Ground	Surface	Total
Neches-Trinity Coastal	2	0.1	5.6	5.7	-	23.6	23.6	-	53.0	53.0
Trinity	3	24.3	-	24.3	48.8	18.6	67.4	49.1	92.3	141.4
Trinity-San Jacinto Coastal	1	21.8	26.2	48.0	17.7	70.0	87.7	25.0	127.2	152.2
San Jacinto	2	356.1	33.6	389.7	231.0	944.2	1,175.2	161.9	2,154.1	2,316.0
San Jacinto-Brazos Coastal	1	80.9	60.0	140.9	42.8	305.0	347.8	42.8	636.4	679.2
Total		483.2	125.4	608.6	340.3	1,361.4	1,701.7	278.8	3,063.0	3,341.8

Source: Texas Water Development Board, The Texas Water Plan, Austin, Texas, November 1968.

capacity of 4,200 megawatts. The nine plants use about 1,900 MGD for once-through cooling and about 17 MGD of water for consumptive cooling purposes. In 1967 there were 18 industrial generating plants in the area with an installed capacity greater than 1,000 kilowatts. The total installed capacity of the 18 plants is about 1,168 megawatts. These plants use about 870 MGD for once-through cooling and about 8 MGD for consumptive cooling purposes. Condenser use and consumptive use are projected to increase to 12,000 MGD and 86 MGD, respectively, by 1990. Comparable projections for 2020 are 24,000 MGD and 288 MGD.

Navigation

The Houston-Galveston-Texas City port complex is one of the largest deep-water harbor areas in the United States. The tonnage handled by these three ports in 1966 was greater than 82 million short tons. Several smaller ports in the Galveston Bay area added about 2 million short tons of shipping to the 1966 total. Principal exports and imports include raw and refined petroleum and petroleum products, chemicals and related products, grain and food products, iron ore and sulphur.

Commercial shipping is generally of two types: Ocean-going traffic which enters Galveston Bay through the entrance channel, and shallow-draft barge traffic which moves through inland channels to and from terminals on the Gulf Intracoastal and other inland waterways. Vessel traffic during 1966 amounted to about 19,500 ocean-going ships and 77,900 shallow-draft barges.

Two planned developments, a shallow-draft channel to open the Trinity River to navigation upstream to the Dallas-Fort Worth area and a new deep-water port facility at Morgan Point, are expected to bring about additional ship and barge traffic in the Galveston Bay area.

Recreation

The major water-oriented recreation activities in the Galveston Bay area are swimming, boating, camping, picnicking, water sports, fishing, and hunting[2/]. In a 27-county study area which included the Galveston Bay area, there were 69,000 feet of established salt-water beaches, 160 boat ramps, and about 2,300 boat-car parking spaces in 1968. A shortage of 9,000 campsites is expected by 1975. Dock and pier space for saltwater fishing totaled 369,000 square feet in 31 structures.

Increases in population, available leisure time and personal incomes contribute to the growing demands for recreational facilities. Because it is adjacent to the most populated metropolitan center in Texas, Galveston Bay is probably the most important coastal area in terms of recreational resources. The full value of this resource cannot be realized unless suitable water quality is maintained.

[2/] Texas Water Quality Board, Socio-Economic Study, Galveston Bay Area. A report to the Federal Water Pollution Control Administration in fulfillment of a contract, Austin, Texas, May 1969.

Irrigation

The total irrigated acreage in the vicinity of Galveston Bay in 1964 was about 258,000 acres. Irrigation water is obtained from ground and surface sources and is used principally for rice production. The irrigated acreage is projected to increase to 278,000 acres in 1990 and 297,000 acres in 2020.

Shellfish Harvesting

Commercial fishing and shellfishing in the Galveston Bay system amounts to nearly five million pounds per year, providing year-round employment for bay area residents as well as seasonal employment for commercial fishermen from Louisiana coastal areas.

The amount and value of oysters harvested from the Galveston Bay estuary has fluctuated significantly from year to year. Oyster harvest data for the 1955-1969 period are presented in Table IV-2. For this period, the annual harvest of oyster meat ranged from 311,000 pounds in 1958 to 4,836,000 pounds in 1965. The corresponding range in dockside value of the meat was $118,000 in 1958 to $1,604,000 in 1966. The average price for oyster meat fluctuated independently of the Galveston Bay supply and ranged from $0.28 per pound in 1957 and 1959 to $0.44 per pound in 1967 and 1968.

Examination of the data shows a sharp increase in oyster harvest beginning in 1959. This change was tempoarily reversed in 1961 by Hurricane Carla which extensively damaged shellfish beds. The harvest rapidly increased between 1961 and 1965, the peak

TABLE IV-2

OYSTER HARVEST AND VALUE
GALVESTON BAY, TEXAS

Year	Total Oyster Harvest: Oyster Meat (1,000 lbs.)	Total Oyster Harvest: Market Value ($1,000)	Average Price ($/lb.)	Bed Area (Acres)	Oyster Yield (lbs./Ac.)
1955	543	160	0.30	8,800	62
1956	986	285	0.29	8,800	112
1957	953	262	0.28	8,800	108
1958	311	118	0.38	8,800	35
1959	1,411	396	0.28	8,800	160
1960	2,296	655	0.29	8,600	268
1961	1,096	329	0.30	8,600	128
1962	1,211	473	0.39	8,600	141
1963	2,618	914	0.35	8,600	305
1964	3,357	1,093	0.33	8,600	391
1965	4,836	1,538	0.32	8,600	562
1966	4,083	1,604	0.39	8,900	458
1967	2,993	1,320	0.44	8,900	336
1968	2,839	1,250	0.44	8,900	319
1969	3,447	N.A.	N.A.	9,100	378
Total	32,980	10,397	-	-	-
Average	2,199	743	0.34	8,760	251
1963-69 Average	3,453	1,270	0.38	8,800	392

Source: Texas Parks & Wildlife Department.

harvest year. During this period, the approved area for shellfish harvesting remained constant. Other factors, such as a decrease in the size limit for harvesting oysters and an increase in the number of out-of-state oystermen taking shellfish from the estuary, are believed to account for much of the increase in harvest. For the past three years, the harvest has been relatively constant, indicating a stable production may be occurring.

V. WATER QUALITY

A. APPLICABLE STANDARDS

The Texas Water Quality Requirements provide specific numerical criteria for fourteen zones in the Galveston Bay area. The locations of these zones are shown in Figure V-1. Table V-1 summarizes the applicable criteria.

The Requirements also provide for classification of shellfish producing areas, as "approved," "conditionally approved," "restricted," or "prohibited," based upon criteria contained in the U.S. Public Health Service manual, "Sanitation of Shellfish Growing Areas," 1965, revised. The criteria for approved shellfish areas are, in summary form:

(1) The area is not so contaminated with fecal material that consumption of shellfish might be hazardous.

(2) The area is not so contaminated with radionuclides or industrial wastes that consumption of the shellfish might be hazardous.

(3) The coliform median MPN of the water does not exceed 70/100 ml, and not more than 10 percent of the samples ordinarily exceed an MPN of 230/100 ml (5 tube decimal dilution test) measured under the most unfavorable hydrographic and pollution conditions.

The Texas Water Quality Requirements and the Shellfish Sanitation Manual are reproduced in Appendix A.

TABLE V-1
SUMMARY OF TEXAS WATER QUALITY STANDARDS APPLICABLE TO GALVESTON BAY AND HOUSTON SHIP CHANNEL

	NUMERICAL CRITERIA								WATER USES[1]	
Zone	Chloride Average mg/l	Sulphate mg/l	Filterable Residue Average mg/l	BOD Average mg/l	Dissolved Oxygen not less than mg/l	MPN Log. Average per 100 ml	pH Range	Temperature °F	Suitable	Known
0901 - Gulf of Mexico at Galveston	20,000	3,000	45,000	1.0	7.0	5.0	7.0-9.0	ALL ZONES - SUMMER 1.5° RISE - SPRING, FALL, WINTER 4° RISE	A,I	A
0902 - Trinity River Tidal	6,000	500	10,000	4.0	6.0	1,000	7.0-9.0		A,I	A
0903 - San Jacinto River Tidal	10,000	1,000	20,000	2.0	4.0	50	6.2-8.5		A,I	A,I
0904 - Houston Ship Channel (Turning Basin area)	4,000	600	9,500	7.0	1.5	100,000	6.0-8.5		E,I,N	I,N
0905 - Houston Ship Channel (San Jacinto Monument to Turning Basin)	7,000	1,000	16,000	5.0	2.0	10,000	6.0-8.5		B,I	B,I
0906 - Houston Ship Channel (Morgan Point to San Jacinto Monument)	10,000	1,000	20,000	2.0	4.0	50	6.2-8.5		A,I	A,I
0907 - Clear Lake	5,000	700	12,000	3.0	6.0	70	7.0-9.0		A,I	A
0908 - Texas City Ship Channel	17,000	2,000	35,000	8.0	3.0	1,000	7.0-9.0		A,I	A
1101 - East Bay	12,000	1,200	25,000	3.0	6.0	70	7.0-9.0		A,I	A
1102 - Galveston Bay (East of Houston Ship Channel, Bounded by Channel Marker 68, Fisher Shoals Day Beacon #1, Lone Oak Bayou, Smith Point, Hanna Reef and Bolivar Peninsula)	12,000	1,200	25,000	4.0	6.0	70	7.0-9.0		A,I	A
1103 - Trinity Bay and Galveston Bay (East of Houston Ship Channel and North of Channel Marker 68 and Fisher Shoals Day Beacon #1)	10,000	700	20,000	5.0	5.0	70	7.0-9.0		A,I	A,I
1104 - Galveston Bay (West of Houston Ship Channel)	12,000	1,500	25,000	6.0	5.0	70	7.0-9.0		A,I	A,I
1105 - West Bay (East of Carancahua Reef)	16,000	2,000	32,000	3.0	5.0	70	7.0-9.0		A,I	A
1106 - West Bay (West of Carancahua Reef)	16,000	2,000	32,000	2.5	6.0	70	7.0-9.0		A,I	A

NARRATIVE CRITERIA APPLICABLE TO ALL ZONES

1. Toxicity and Toxic Materials - These waters shall not exhibit either acute or chronic toxicity (or other harmful effect) to human, animal, or aquatic life to such an extent as to interfere with uses of the waters.
2. Free or Floating Oil - Substantially free from oil.
3. Foaming or Frothing Material - None of a persistent nature.
4. Other - The control of other substances not heretofore mentioned will be guided by the U.S. Public Health Service manual, "Sanitation of Shellfish Growing Area," 1965 revision. Where waters are not shellfish growing areas, it is required only that waters entering or contiguous to a shellfish growing area not interfere with the shellfish growing area.
5. Radioactive Materials - Levels of ionizing radiation and radioactive materials of all kinds, from both dissolved and suspended matter, shall be regulated by the Texas Radiation Control Act, Article 4590 (f), Revised Civil Statutes of Texas, and the Texas Regulations for Control of Radiation issued thereunder.

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[1] Key to Water Uses.
Group A - Contact Recreation, Non-Contact Recreation, Fish and Wildlife, Fishing, Aesthetics, Navigation.
Group B - Non-Contact Recreation, Aesthetics, Navigation.
Group E - Aesthetics.
Group I - Industrial Cooling Water.
Group N - Navigation.

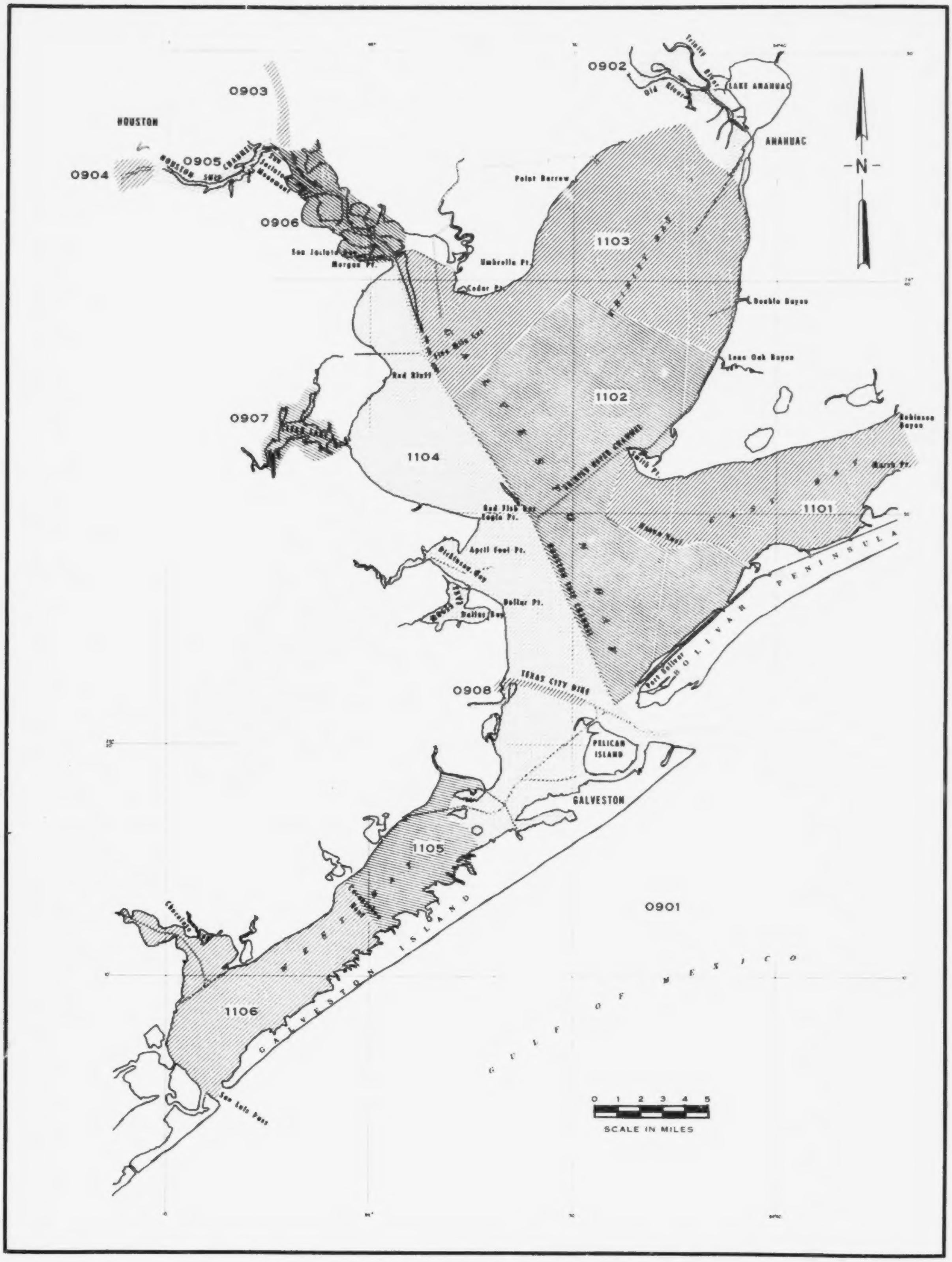

0903
HOUSTON
0905
0904
HOUSTON SHIP
0906
San Jacinto Bay
Morgan Pt.
0902
Trinity River
Old River
LAKE ANAHUAC
ANAHUAC
N
Point Barrow
Umbrella Pt.
Cedar Pt.
1103
TRINITY BAY
Double Bayou
Lone Oak Bayou
1102
Red Bluff
0907
CLEAR LAKE
1104
TRINITY RIVER CHANNEL
Smith Pt.
Robinson Bayou
Marsh Pt.
EAST BAY
1101
Red Fish Bar
Eagle Pt.
April Fool Pt.
Dickinson Bay
Dollar Pt.
Moses Lake
Dollar Bay
GALVESTON BAY
HOUSTON SHIP CHANNEL
BOLIVAR PENINSULA
Port Bolivar
0908
TEXAS CITY DIKE
PELICAN ISLAND
GALVESTON
1105
0901
WEST BAY
Chocolate Bay
GALVESTON ISLAND
GULF OF MEXICO
1106
San Luis Pass
0 1 2 3 4 5
SCALE IN MILES

Figure V-1 Water Quality Standards Zones in the Galveston Bay Area

30b

B. COLIFORM

Coliform data obtained by the Galveston Bay Study for the period July 1968 through June 1970 show that shellfish harvesting criteria have been exceeded a significant percentage of the time during the shellfish harvesting season in approved areas and almost continuously in closed or prohibited areas (Table V-2). Classification of shellfish areas and locations of sampling stations are illustrated in Figure V-2. Samples are collected monthly from a network of widely separated stations.

Although the total coliform median limit of 70/100 ml is met at all locations in the open areas, the 230/100 ml limit is exceeded more than 10 percent of the time in at least three locations in, or immediately adjacent to, approved harvesting areas. Two of these locations are in Galveston Bay (Stations 4 and 23) and one in West Bay (Station 13). Total coliform concentrations were acceptable in the area of the most productive shellfish reef (Station 28).

A supplementary fecal coliform criterion was recommended and discusssed at the Fifth National Shellfish Sanitation Workshop (1964). It was proposed that a median fecal coliform MPN of 7.8/100 ml not be exceeded and that not more than 10 percent of samples should exceed 33/100 ml. Fecal coliform organisms have been demonstrated to almost exclusively originate from the digestive tract of man and other warm blooded animals and are, therefore, presumedly a better

TABLE V-2

MEDIAN VALUES OF TOTAL COLIFORM CONCENTRATIONS AND PERCENTAGE OF SAMPLES GREATER THAN 230 COLIFORM/100 ML AT SELECTED STATIONS IN GALVESTON BAY FOR THE PERIODS DECEMBER 1968-APRIL 1969 AND DECEMBER 1969-APRIL 1970

Station Number	Area Classification	Surface		1/3 Depth		1/2 Depth		2/3 Depth		Bottom	
		Median	Percent > 230	Median	Percent > 230	Median	Percent > 230	Median	Percent > 230	Median	Percent > 230
1	Closed	79	18	27	9			14	18	8	9
2	Closed	79	30			130	36				
3	Closed	49	9	33	18			49	9	79	18
4	Edge of open area	33	45	49	55			33	45	33	55
5	Closed	130	36	310	64			330	57	49	27
12	Closed	13	36			14	18				
13	Open	2	9			< 2	18				
14	Open	2	0			5	0				
15	Closed	11	9			17	9				
16	Closed	490	73			940	64				
17	Closed	11	0			17	9				
18	Closed Conditional	8	9			7	9				
19	Closed	330	45			330	55				
20	Closed	230	45			330	55				
21	Closed	700	74			700	74				
22	Closed	49	18			49	18				
23	Open	33	27			26	18				
24	Closed	240	55			221	45				
25	Closed	1,600	73			790	73				
26	Closed	23	18			14	18				
27	Closed	130	36			33	36				
28	Open	5	9			7	9				
29	Open	2	0			5	0				
30	Open	2	0			2	0				
31	Closed	790	91			490	73				
32	Closed	13,000	100			33,000	100				
33	Closed	2,400	100	3,300	91			1,720	82	630	73
38	Closed	460	67	175	33 ---Samples December 1969-April 1970 only.						

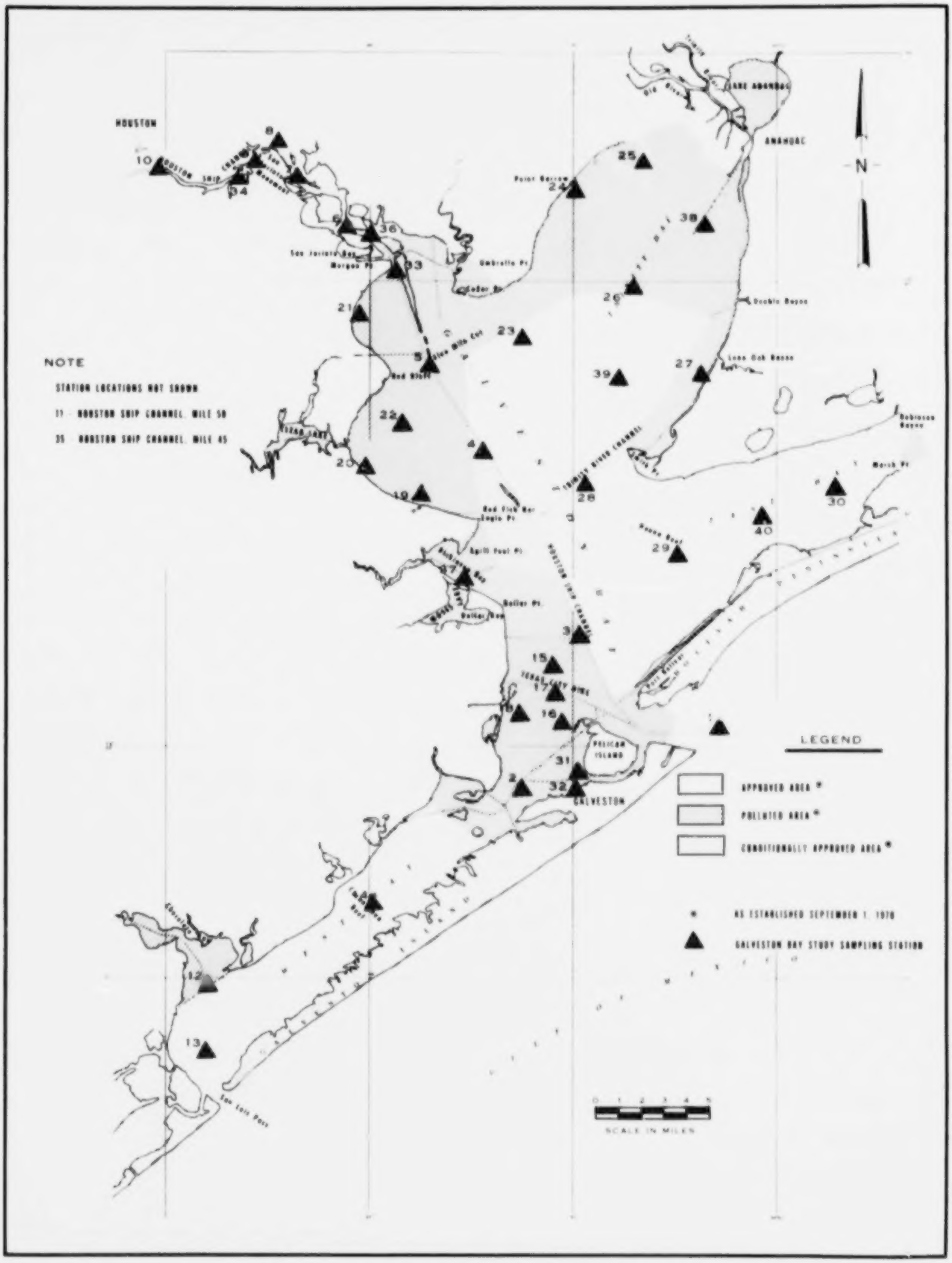

HOUSTON
10
HOUSTON SHIP CHANNEL
8
34
6
36
San Jacinto Bay
Morgan Pt
33
Umbrella Pt
Cedar Bayou
21
5
Red Bluff
23
Point Barrow
24
25
LAKE ANAHUAC
Trinity River
Old River
ANAHUAC
N
38
26
Double Bayou
27
Lone Oak Bayou
39
Robinson Bayou
22
Clear Lake
4
TRINITY RIVER CHANNEL
Smith Pt
20
19
28
Red Fish Bar
Eagle Pt
30
Marsh Pt
40
Hanna Reef
29
HOUSTON SHIP CHANNEL
Dickinson Bay
37
Dollar Pt
3
15
TEXAS CITY DIKE
17
16
PELICAN ISLAND
31
2
32
GALVESTON
Port Bolivar
BOLIVAR PENINSULA
GALVESTON ISLAND
Chocolate Bay
12
13
San Luis Pass
NOTE
STATION LOCATIONS NOT SHOWN
11 - HOUSTON SHIP CHANNEL, MILE 50
35 - HOUSTON SHIP CHANNEL, MILE 45
LEGEND
APPROVED AREA *
POLLUTED AREA *
CONDITIONALLY APPROVED AREA *
* AS ESTABLISHED SEPTEMBER 1, 1970
GALVESTON BAY STUDY SAMPLING STATION
0 1 2 3 4 5
SCALE IN MILES

Figure V - 2 Galveston Bay Study Sampling Stations and Classifications of Shellfish Harvesting Areas

indicator of recent pollution from these sources than total coliform. The concentrations for Galveston Bay are summarized in Table V-3. The same pattern as total coliform is demonstrated, with the recommended criteria being violated at the same three locations in the open areas. The median concentration near the most productive reef was less than the lower limit tested and no measured values exceeded 33/100 ml during the 1969 and 1970 harvesting seasons.

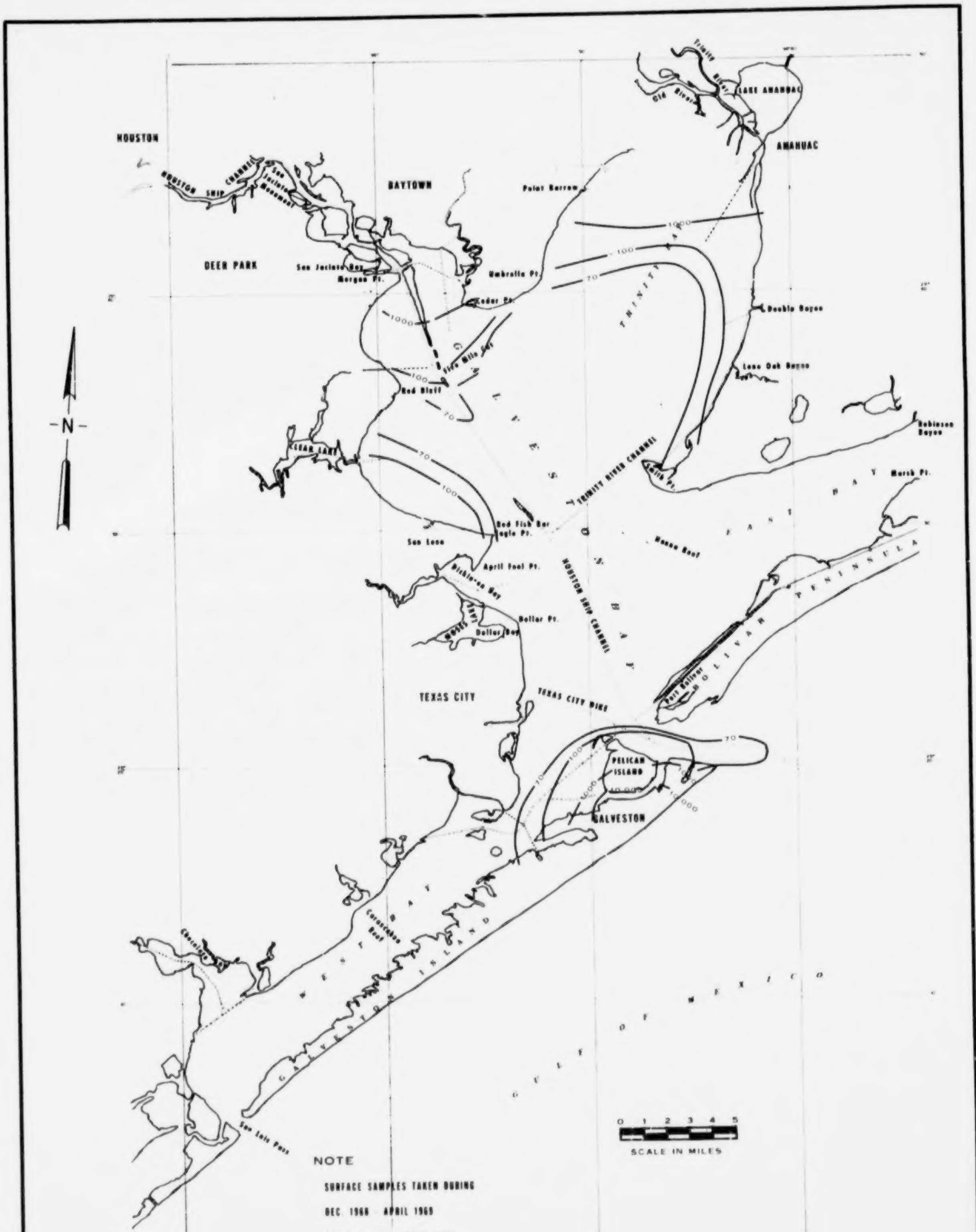
Lines of equal total coliform concentrations (iso-lines) as well as percentage of time that concentrations exceeded 230/100 ml are shown in Figures V-3 and V-4. The excessive concentrations of coliform pollution emanate primarily from the Houston Ship Channel. Increased concentrations of bacteriological pollution in Galveston Bay are attributable to waste discharges from the Clear Lake area and the City of Galveston. Concentrations are slightly higher in the Chocolate Bayou and East Bay areas. The iso-lines also demonstrate that, in a large portion of the approved shellfish harvesting area, total coliform concentrations will exceed 230/100 ml more than 10 percent of the time.

To determine the pattern of coliform pollution under differing hydrological and meteorological conditions, iso-lines were analyzed for January 14, February 18, and March 18, 1969 as well as January 14, February 10, and March 10, 1970. These coliform distributions are illustrated in Figures V-5 through V-10. Meteorological and hydrological conditions existing prior to and on the date of

TABLE V-3

MEDIAN FECAL COLIFORM CONCENTRATIONS AND PERCENTAGE OF SAMPLES WITH FECAL COLIFORM CONCENTRATIONS GREATER THAN 33/100 ML AT SELECTED STATIONS IN GALVESTON BAY FOR THE PERIODS DECEMBER 1968-APRIL 1969 AND DECEMBER 1969-APRIL 1970

Station Number	Area Classification	Surface		1/3 Depth		1/2 Depth		2/3 Depth		Bottom	
		Median	Percent > 33	Median	Percent > 33	Median	Percent > 33	Median	Percent > 33	Median	Percent > 33
1		20	36	7	9			5	9	4	9
2		22	36			33	45				
3		17	18	13	36			17	27	21	36
4	Edge of open area	2	0	8	18			8	9	5	18
5		23	36	23	45			23	45	23	27
12		5	36			2	18				
13	Open	< 2	18			< 2	18				
14	Open	< 2	0			< 2	0				
15		5	45			2	27				
16		221	73			330	73				
17		5	0			7	9				
18	Conditional	< 2	9			2	9				
19		46	55			31	45				
20		33	45			49	45				
21		49	64			130	74				
22		5	9			5	0				
23	Open	5	27			2	18				
24		17	27			17	18				
25		79	73			33	55				
26		2	0			4	0				
27		13	36			2	27				
28	Open	< 2	0			< 2	0				
29	Open	< 2	0			< 2	0				
30	Open	< 2	0			< 2	0				
31		490	100			330	82				
32		7,000	100			7,900	100				
33		1,090	100	490	100			330	100	130	91
38		40	50			14	33				


HOUSTON
HOUSTON SHIP CHANNEL
San Jacinto Monument
BAYTOWN
DEER PARK
San Jacinto Bay
Morgan Pt.
Umbrella Pt.
Cedar Pt.
Point Barrow
Trinity River
Old River
LAKE ANAHUAC
ANAHUAC
TRINITY BAY
Double Bayou
Lone Oak Bayou
Robinson Bayou
Five Mile Cut
Red Bluff
CLEAR LAKE
GALVESTON BAY
TRINITY RIVER CHANNEL
Smith Pt.
EAST BAY
Marsh Pt.
Red Fish Bar
Eagle Pt.
San Leon
Hanna Reef
April Fool Pt.
Dickinson Bay
HOUSTON SHIP CHANNEL
Dollar Pt.
Dollar Bay
TEXAS CITY
TEXAS CITY DIKE
Port Bolivar
BOLIVAR PENINSULA
PELICAN ISLAND
GALVESTON
WEST BAY
Carancahua Reef
GALVESTON ISLAND
GULF OF MEXICO
Chocolate Bay
San Luis Pass
1000
100
70
10,000
N
0 1 2 3 4 5
SCALE IN MILES

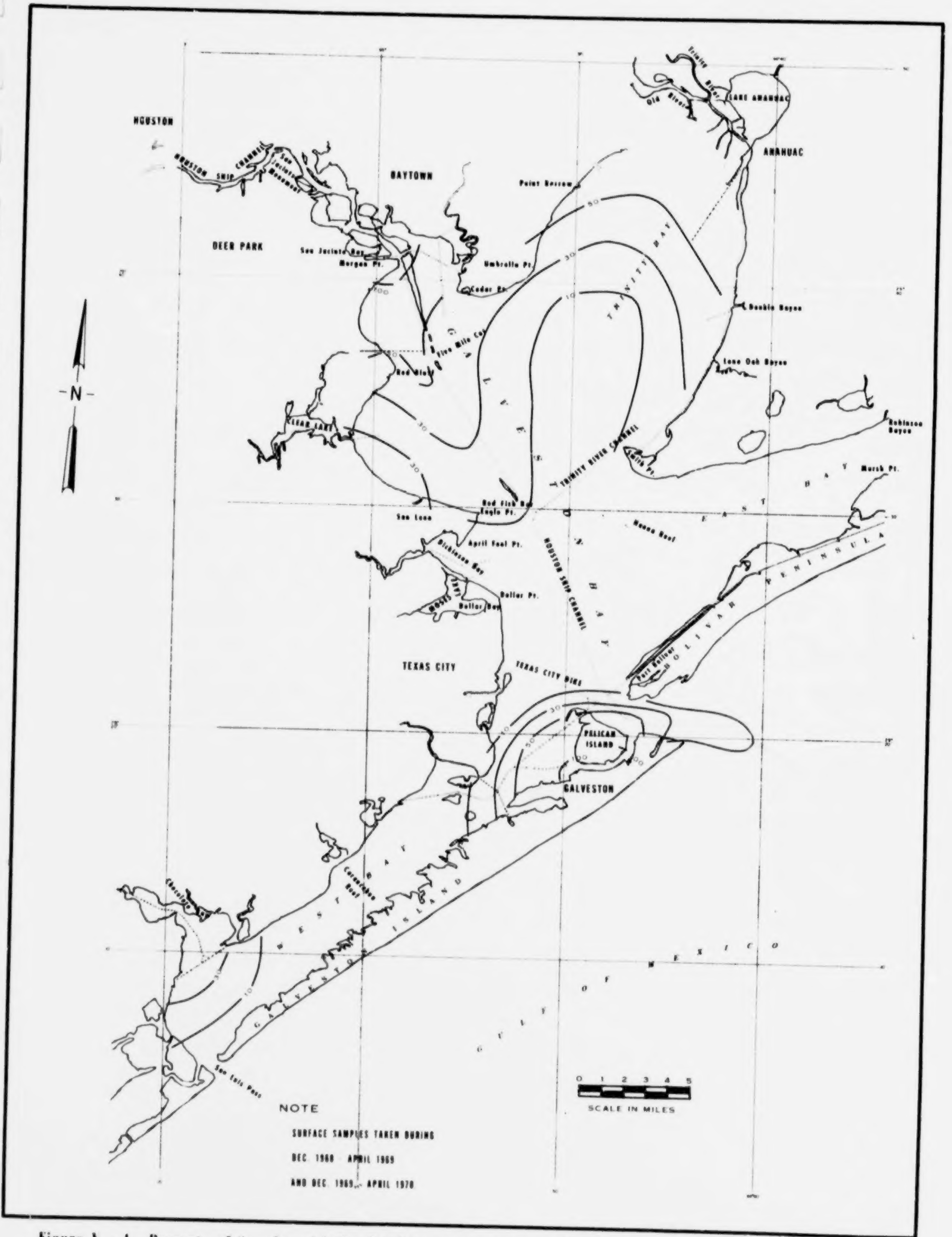
NOTE

SURFACE SAMPLES TAKEN DURING

DEC 1968 APRIL 1969

AND DEC 1969 APRIL 1970

Figure V - 3 Isolines of Median Coliform Concentrations, Galveston Bay.


HOUSTON
HOUSTON SHIP CHANNEL
San Jacinto Monument
BAYTOWN
DEER PARK
San Jacinto Bay
Morgan Pt.
Umbrella Pt.
Cedar Pt.
Point Barrow
Trinity River
Old River
LAKE ANAHUAC
ANAHUAC
TRINITY BAY
Double Bayou
Lone Oak Bayou
Robinson Bayou
Five Mile Cut
Red Bluff
CLEAR LAKE
GALVESTON BAY
TRINITY RIVER CHANNEL
Smith Pt.
Marsh Pt.
EAST BAY
Red Fish Bar
Eagle Pt.
San Leon
April Fool Pt.
Dickinson Bay
Moses Lake
Dollar Bay
Dollar Pt.
HOUSTON SHIP CHANNEL
TEXAS CITY
TEXAS CITY DIKE
Port Bolivar
BOLIVAR PENINSULA
PELICAN ISLAND
GALVESTON
WEST BAY
Carancahua Reef
Chocolate Bay
GALVESTON ISLAND
San Luis Pass
GULF OF MEXICO
100
50
30
10
-N-
0 1 2 3 4 5
SCALE IN MILES

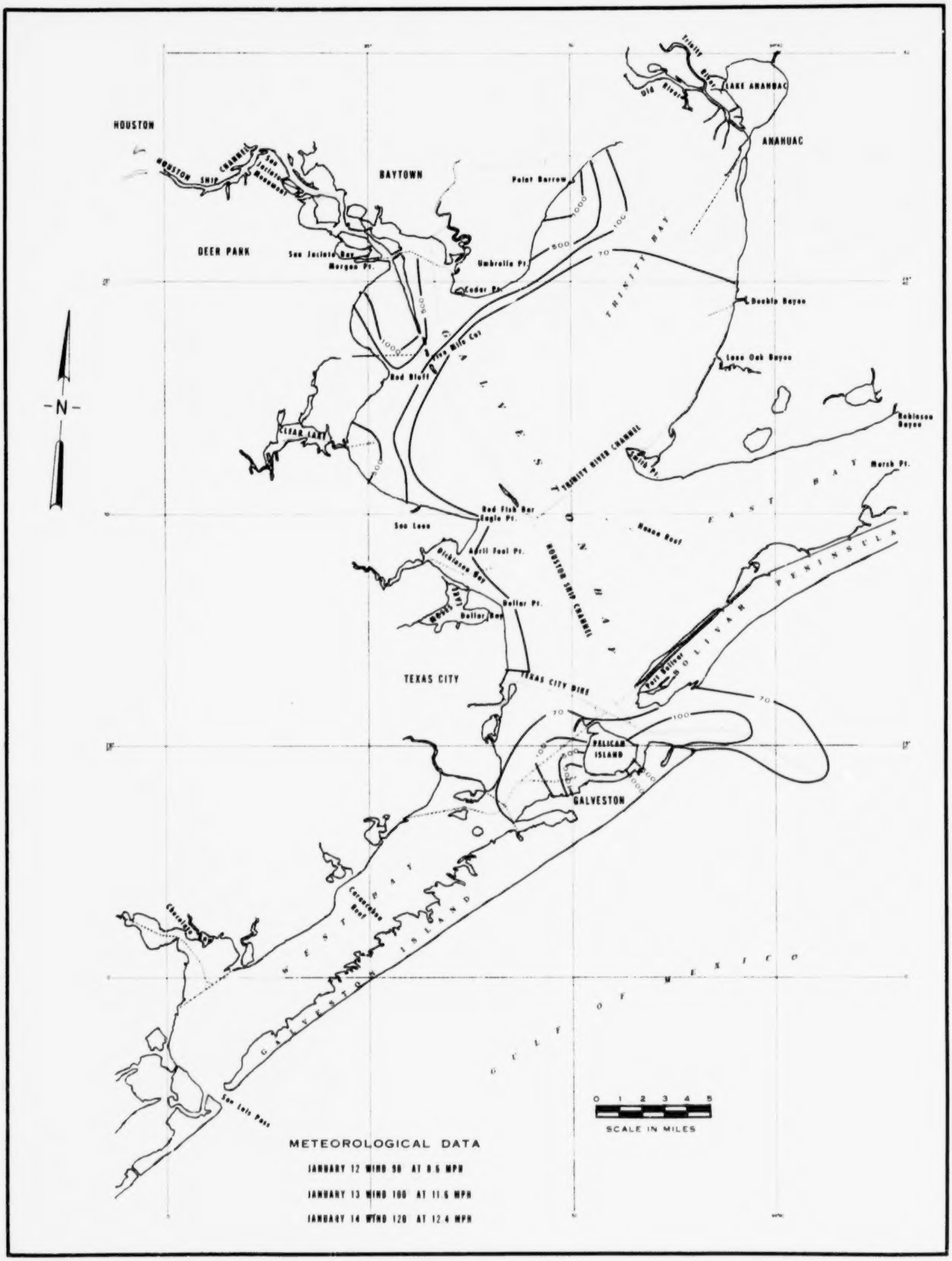
NOTE

SURFACE SAMPLES TAKEN DURING

DEC. 1968 - APRIL 1969

AND DEC. 1969 - APRIL 1970

Figure V - 1 Percent of Samples with Total Coliform Concentrations Greater Than 230/100 ml. Galveston Bay.


HOUSTON
HOUSTON SHIP CHANNEL
San Jacinto Monument
BAYTOWN
DEER PARK
San Jacinto Bay
Morgan Pt.
Umbrella Pt.
Cedar Pt.
Point Barrow
Trinity River
Old River
LAKE ANAHUAC
ANAHUAC
TRINITY BAY
Double Bayou
Lone Oak Bayou
Robinson Bayou
Smith Pt.
Marsh Pt.
EAST BAY
BOLIVAR PENINSULA
Port Bolivar
Five Mile Cut
Red Bluff
CLEAR LAKE
TRINITY RIVER CHANNEL
GALVESTON BAY
Red Fish Bar
Eagle Pt.
San Leon
Hanna Reef
April Fool Pt.
Dickinson Bay
Moses Lake
Dollar Bay
Dollar Pt.
HOUSTON SHIP CHANNEL
TEXAS CITY
TEXAS CITY DIKE
PELICAN ISLAND
GALVESTON
WEST BAY
Carancahua Reef
Chocolate Bay
GALVESTON ISLAND
San Luis Pass
GULF OF MEXICO
N
1000
500
100
70
1000
500
500
70
100
100
500
1000
70
100
0 1 2 3 4 5
SCALE IN MILES

METEOROLOGICAL DATA

JANUARY 12 WIND 90 AT 8.6 MPH

JANUARY 13 WIND 100 AT 11.6 MPH

JANUARY 14 WIND 120 AT 12.4 MPH

Figure V - 5 Isolines of Total Coliform Concentrations–Galveston Bay - January 11, 1969

34 a

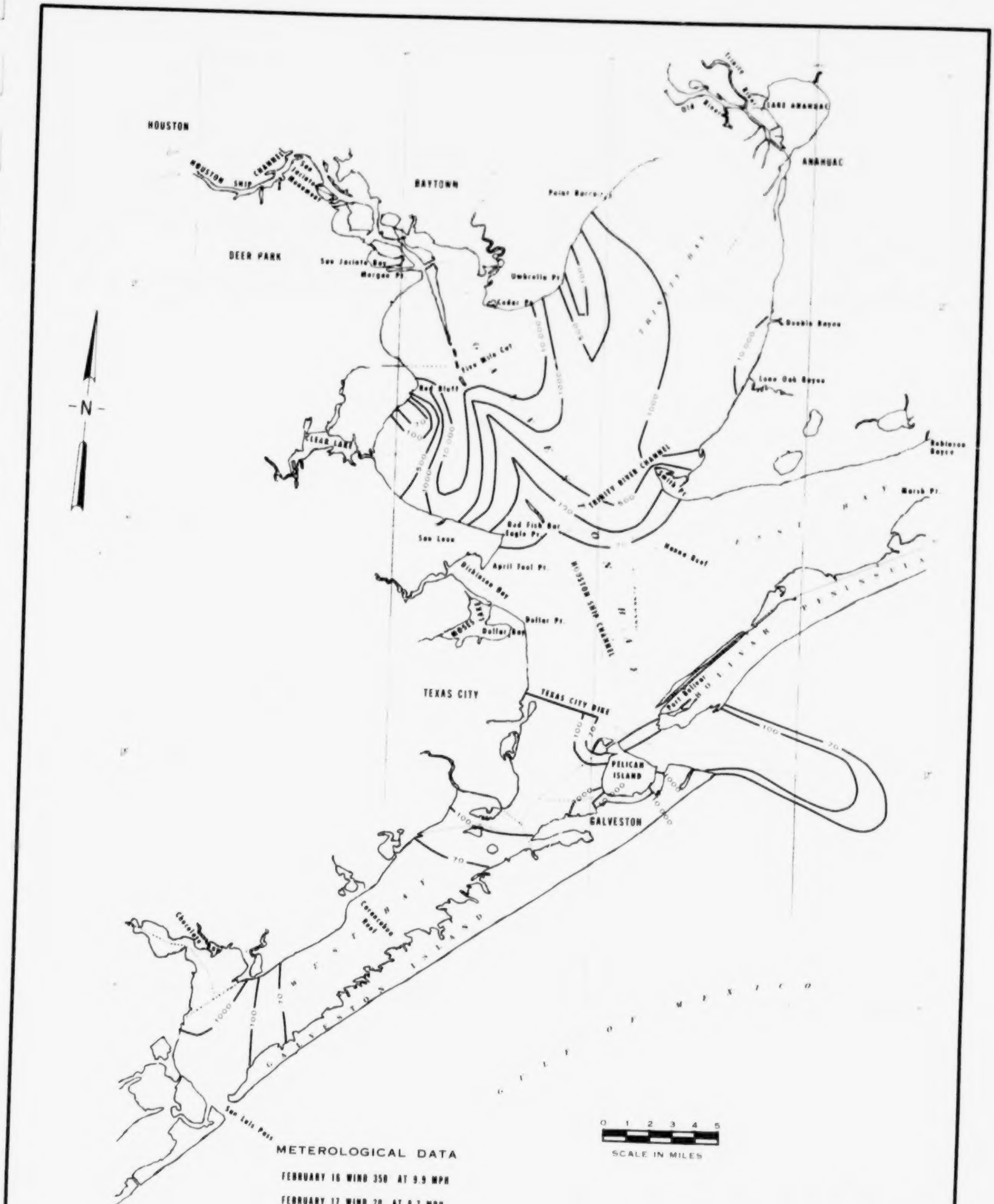

HOUSTON
HOUSTON SHIP CHANNEL
San Jacinto Monument
BAYTOWN
DEER PARK
San Jacinto Bay
Morgan Pt.
Point Barrow
Trinity River
Old River
LAKE ANAHUAC
ANAHUAC
Umbrella Pt.
Cedar Pt.
Five Mile Cut
Red Bluff
Clear Lake
TRINITY BAY
Double Bayou
Lone Oak Bayou
Robinson Bayou
TRINITY RIVER CHANNEL
Smith Pt.
Marsh Pt.
EAST BAY
Red Fish Bar
Eagle Pt.
San Leon
Hanna Reef
April Fool Pt.
Dickinson Bay
Moses Lake
Dollar Pt.
Dollar Bay
HOUSTON SHIP CHANNEL
GALVESTON BAY
TEXAS CITY
TEXAS CITY DIKE
Port Bolivar
BOLIVAR PENINSULA
PELICAN ISLAND
GALVESTON
WEST BAY
Carancahua Reef
Chocolate Bay
GALVESTON ISLAND
San Luis Pass
GULF OF MEXICO
70
100
500
1000
5000
10,000
N
0 1 2 3 4 5
SCALE IN MILES
METEROLOGICAL DATA
FEBRUARY 16 WIND 350 AT 9.9 MPH
FEBRUARY 17 WIND 20 AT 8.7 MPH
FEBRUARY 18 WIND 360 AT 9.4 MPH

Figure V - 6 Isolines of Total Coliform Concentrations–Galveston Bay - February 18, 1969

34e

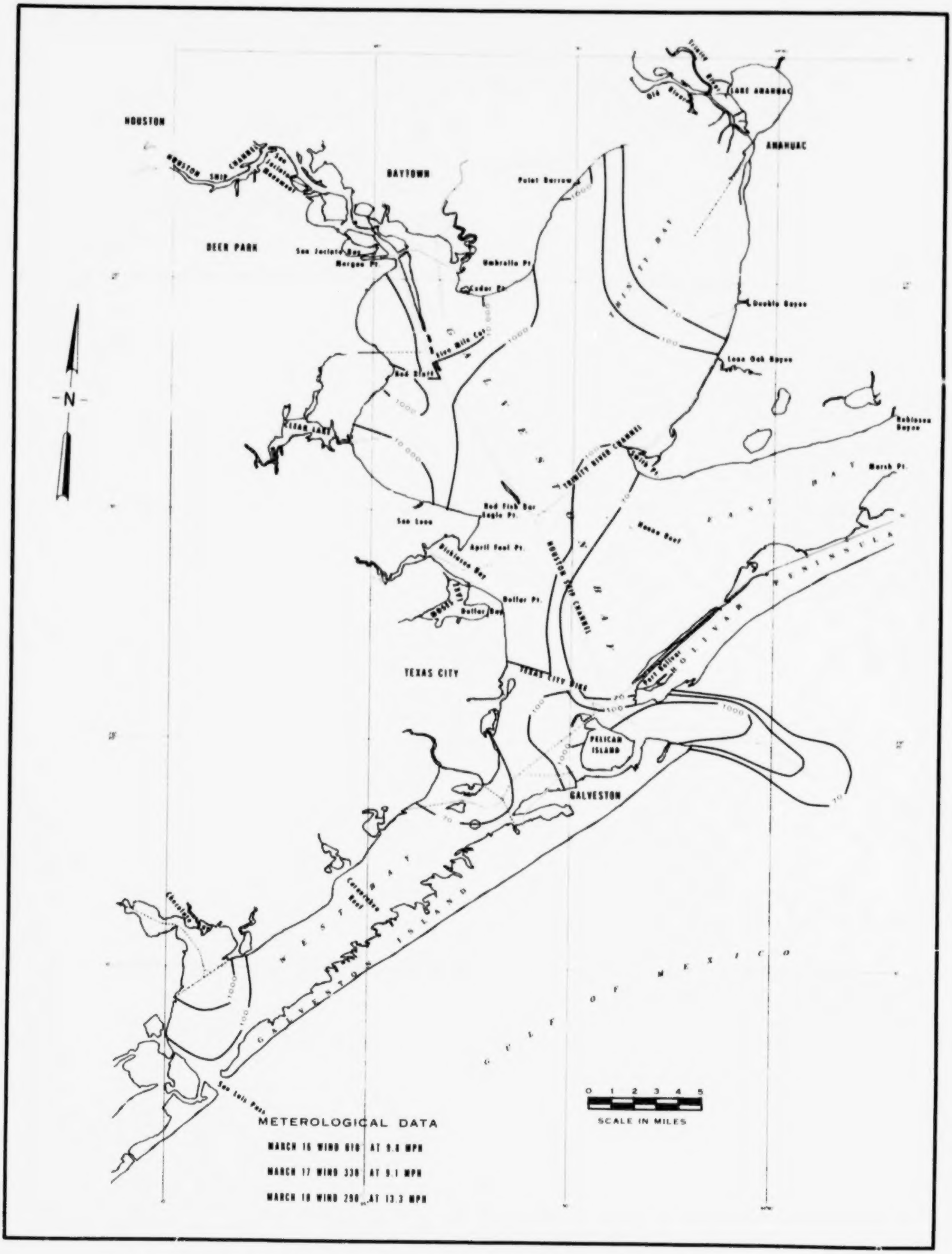

HOUSTON
HOUSTON SHIP CHANNEL
San Jacinto Monument
BAYTOWN
DEER PARK
San Jacinto Bay
Morgan Pt.
Umbrella Pt.
Cedar Bayou
Five Mile Cut
Red Bluff
Clear Lake
Point Barrow
Trinity River
Old River
LAKE ANAHUAC
ANAHUAC
TRINITY BAY
Double Bayou
Lone Oak Bayou
Robinson Bayou
March Pt.
TRINITY RIVER CHANNEL
Smith Pt.
EAST BAY
Red Fish Bar
Eagle Pt.
San Leon
April Fool Pt.
Dickinson Bay
Moses Lake
Dollar Pt.
Dollar Bay
Hanna Reef
HOUSTON SHIP CHANNEL
GALVESTON BAY
TEXAS CITY
TEXAS CITY DIKE
Port Bolivar
BOLIVAR PENINSULA
PELICAN ISLAND
GALVESTON
WEST BAY
Carancahua Reef
GALVESTON ISLAND
Chocolate Bay
San Luis Pass
GULF OF MEXICO
10,000
1000
100
70
N
0 1 2 3 4 5
SCALE IN MILES
METEROLOGICAL DATA
MARCH 16 WIND 010° AT 9.8 MPH
MARCH 17 WIND 330° AT 9.1 MPH
MARCH 18 WIND 290° AT 13.3 MPH

Figure V - 7 Isolines of Total Coliform Concentrations–Galveston Bay - March 18, 1969

34 f

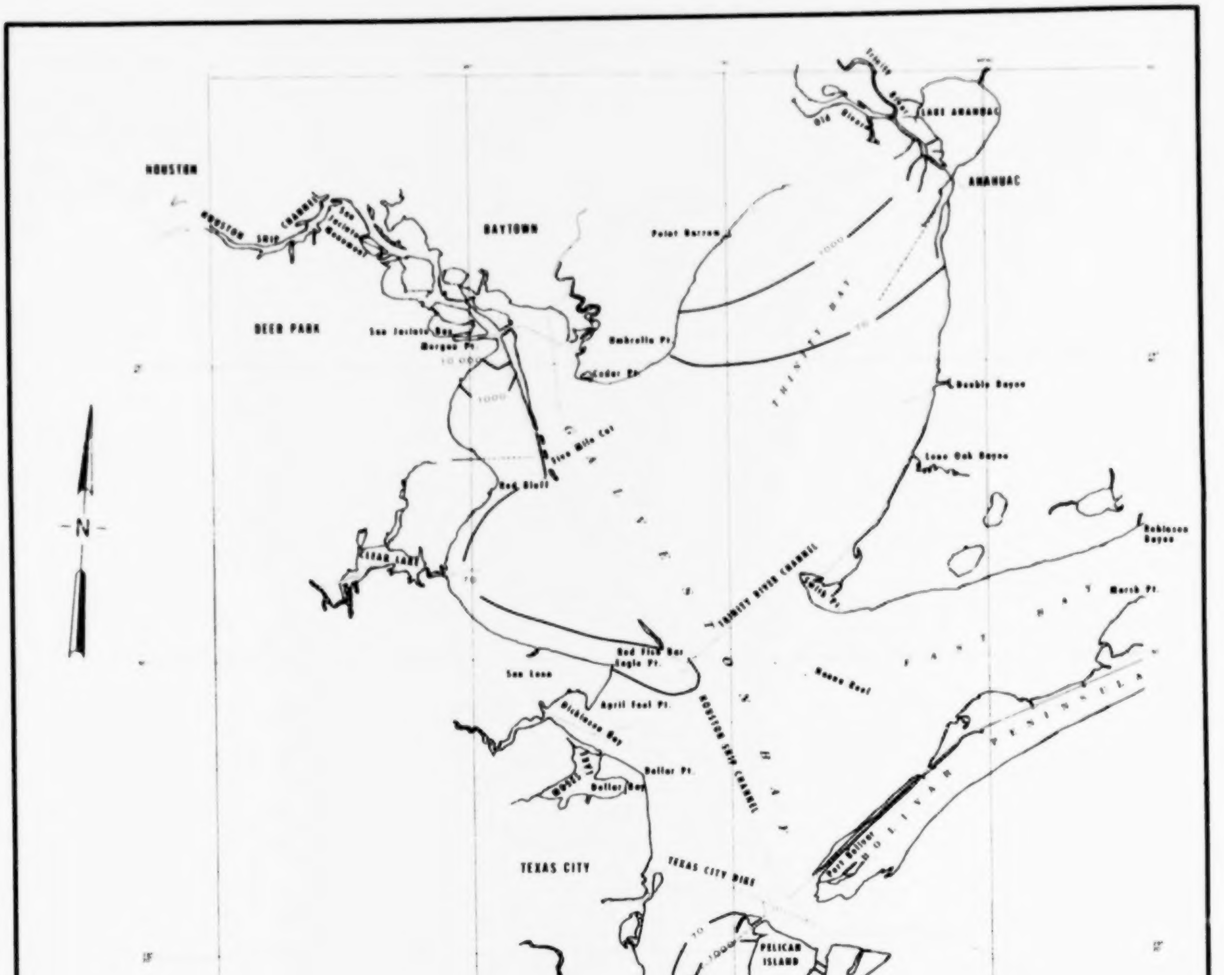

Trinity River
LAKE ANAHUAC
Old River
ANAHUAC
HOUSTON
HOUSTON SHIP CHANNEL
San Jacinto Monument
BAYTOWN
Point Barrow
1000
10
TRINITY BAY
DEER PARK
San Jacinto Bay
Morgan Pt.
10,000
Umbrella Pt.
Cedar Pt.
Double Bayou
1000
Five Mile Cut
Red Bluff
Lone Oak Bayou
Robinson Bayou
Clear Lake
10
TRINITY RIVER CHANNEL
Smith Pt.
Marsh Pt.
EAST BAY
Red Fish Bar
Eagle Pt.
San Leon
Moses Reef
April Fool Pt.
Dickinson Bay
Dollar Pt.
Dollar Bay
Moses Lake
HOUSTON SHIP CHANNEL
GALVESTON BAY
BOLIVAR PENINSULA
Port Bolivar
TEXAS CITY
TEXAS CITY DIKE
10
1000
PELICAN ISLAND
GALVESTON
WEST BAY
Carancahua Reef
Chocolate Bay
GALVESTON ISLAND
GULF OF MEXICO
San Luis Pass
0 1 2 3 4 5
SCALE IN MILES
N
METEOROLOGICAL DATA
JANUARY 11 WIND 200 AT 6.0 MPH
JANUARY 12 WIND 10 AT 4.5 MPH
JANUARY 13 WIND 60 AT 5.0 MPH

Figure V - 8 Isolines of Total Coliform Concentrations - Galveston Bay - January 13, 1970

349

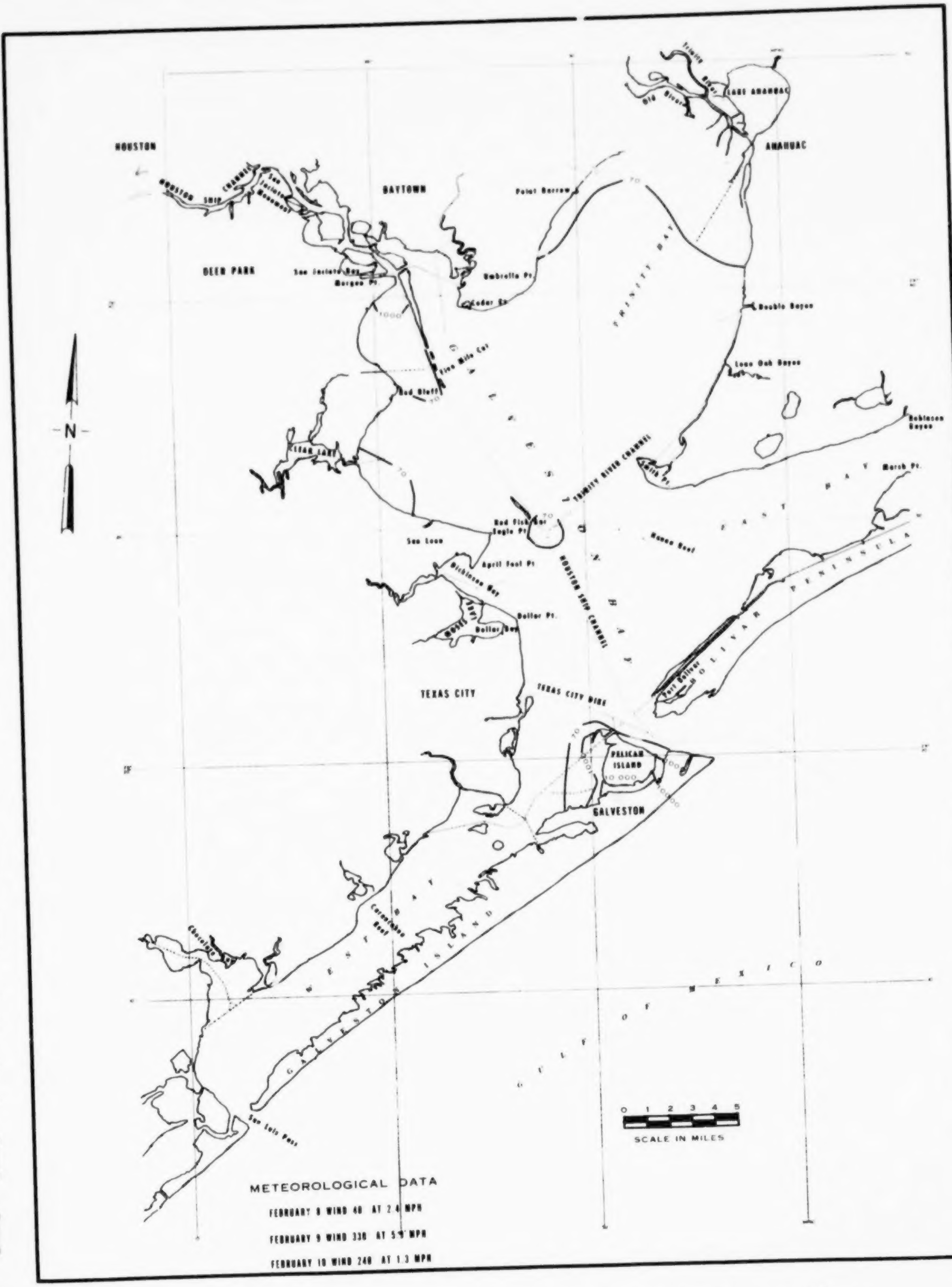

HOUSTON
HOUSTON SHIP CHANNEL
San Jacinto Monument
BAYTOWN
DEER PARK
San Jacinto Bay
Morgan Pt.
Point Barrow
Umbrella Pt.
Cedar Bayou
Trinity River
Old River
LAKE ANAHUAC
ANAHUAC
TRINITY BAY
Double Bayou
Lone Oak Bayou
Robinson Bayou
Smith Pt.
Five Mile Cut
Red Bluff
Clear Lake
TRINITY RIVER CHANNEL
GALVESTON BAY
EAST BAY
Marsh Pt.
Hanna Reef
Red Fish Bar
Eagle Pt.
San Leon
April Fool Pt.
Dickinson Bay
Dollar Pt.
Dollar Bay
HOUSTON SHIP CHANNEL
BOLIVAR PENINSULA
Port Bolivar
TEXAS CITY
TEXAS CITY DIKE
PELICAN ISLAND
GALVESTON
WEST BAY
Carancahua Reef
Chocolate Bay
GALVESTON ISLAND
San Luis Pass
GULF OF MEXICO
N
70
1000
10 000
0 1 2 3 4 5
SCALE IN MILES
METEOROLOGICAL DATA
FEBRUARY 8 WIND 40 AT 2.4 MPH
FEBRUARY 9 WIND 330 AT 5.9 MPH
FEBRUARY 10 WIND 240 AT 1.3 MPH

Figure V-9 Isolines of Total Coliform Concentrations-Galveston Bay - February 10, 1970

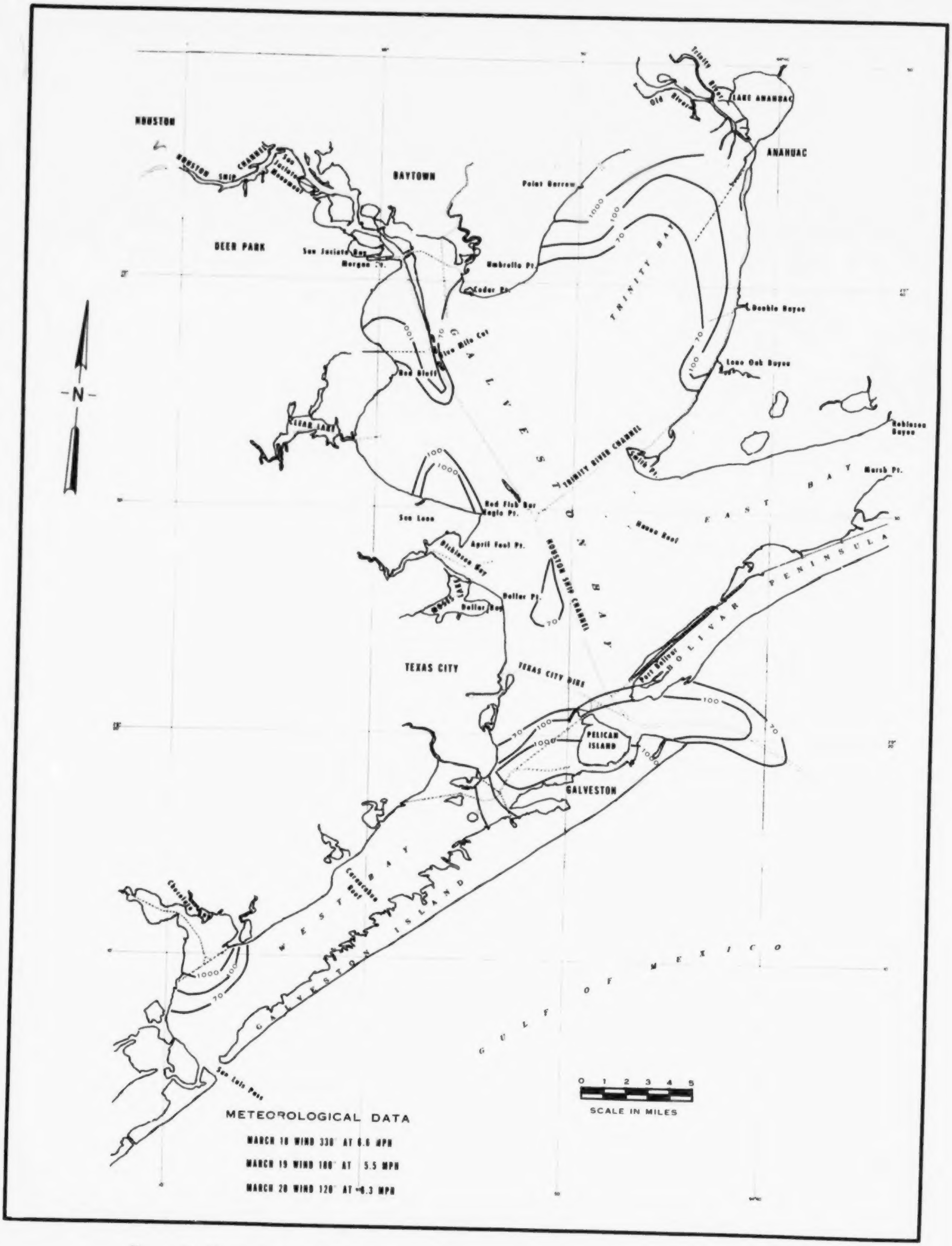

HOUSTON
HOUSTON SHIP CHANNEL
San Jacinto Monument
BAYTOWN
DEER PARK
San Jacinto Bay
Morgan Pt.
Point Barrow
Umbrella Pt.
Cedar Pt.
Trinity River
Old River
LAKE ANAHUAC
ANAHUAC
TRINITY BAY
Double Bayou
Lone Oak Bayou
Robinson Bayou
Smith Pt.
Marsh Pt.
EAST BAY
Five Mile Cut
Red Bluff
Clear Lake
GALVESTON BAY
TRINITY RIVER CHANNEL
Red Fish Bar
Eagle Pt.
San Leon
April Fool Pt.
Dickinson Bay
Moses Lake
Dollar Bay
Dollar Pt.
Hanna Reef
HOUSTON SHIP CHANNEL
TEXAS CITY
TEXAS CITY DIKE
Port Bolivar
BOLIVAR PENINSULA
PELICAN ISLAND
GALVESTON
WEST BAY
Carancahua Reef
Chocolate Bay
GALVESTON ISLAND
San Luis Pass
GULF OF MEXICO
1000
100
70
-N-
0 1 2 3 4 5
SCALE IN MILES
METEOROLOGICAL DATA
MARCH 18 WIND 330° AT 6.6 MPH
MARCH 19 WIND 100° AT 5.5 MPH
MARCH 20 WIND 120° AT 6.3 MPH

Figure V-10 Isolines of Total Coliform Concentrations-Galveston Bay - March 10, 1970

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sampling were examined. Strong north or northwest winds, with accompanying precipitation, cause excessively high coliform concentrations in the approved harvesting area. On February 18, 1969, after three days of strong northerly winds and 1.8 inches of rain recorded on February 13, virtually the entire approved area of the Bay had total coliform concentrations in excess of 100/100 ml with 542/100 ml observed immediately adjacent to the most productive shellfish reefs. Similar conditions occurred on March 18, 1969 (variable northerly winds with 1.45 inches of rain recorded from March 15-17) and again, coliform concentrations exceeded 100/100 ml in nearly all of the approved areas with the exception of East Bay. The shellfish areas in Galveston Bay were temporarily closed during this period. In contrast, winds from the northeast, east, or southeast with no precipitation are the most favorable conditions for low coliform concentrations in the approved harvesting areas as evidenced by the iso-lines for January 14, 1969, January 13, 1970, and February 10, 1970. These meteorological and hydrological conditions minimize the effect of pollution discharged to the Houston Ship Channel and Clear Lake areas by confining it to the immediate areas of discharge. Periods of rainfall cause significant bacteriological contributions from Double Bayou on the east side of the Bay to the approved harvesting area in Galveston Bay, and from Chocolate Bayou to approved areas in West Bay. Coliform pollution is also contributed from the Point Barrow area. During relatively calm conditions, allowable coliform concentrations for shellfish

It is estimated, from samples collected in February 1969 by the Texas Water Quality Board, that 1,600 pounds per day of lead, 7,900 pounds per day of zinc, 5,000 pounds per day of cadmium, and 300 pounds per day of chromium are discharged primarily to the Houston Ship Channel. The Houston Ship Channel also receives 400 pounds per day of phenols and at least 1,000 pounds per day of cyanide, a highly toxic chemical, principally from the Armco Steel Company. Observed concentrations of metals in the Houston Ship Channel near water supply intakes are summarized in Table V-4 from the Texas Water Quality Board data and from WQO-EPA data collected during November 1970 in Galveston Bay and the Houston Ship Channel. The Federal Water Quality Administration's sampling locations are shown in Figure V-11. Although numerical criteria have not been established for most of these substances, maximum concentrations observed were grossly in excess of natural background ranging from 8.5 times greater than background for nickel to 108,000 times greater than background for chromium. Concentrations of metals found at all sampling stations in Galveston Bay and the Houston Ship Channel by WQO-EPA indicate widespread and relatively uniform contamination throughout the system.

Sediment samples were collected from the Houston Ship Channel, West Bay near Galveston, and Trinity Bay during the summer of 1969[1].

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[1] Copeland, B. J., and W. G. Fruh, Ecological Studies of Galveston Bay, Final Report to the Texas Water Quality Board - Contract IAC (68-69), 408, 1969.

TABLE V-4

CONCENTRATIONS OF HEAVY METALS
GALVESTON BAY - HOUSTON SHIP CHANNEL

Metal	Background Sea Water Concentration* µg/l**	Maximum Observed Concentration µg/l		Order of Magnitude Above Background	
		1/	2/	1/	2/
Lead	0.03	1,900	20	63,300	-
Zinc	10.0	14,000	1,550	1,400	155
Cadmium	80.0	1,200	-	15	-
Copper	3.0	10,800	360	3,600	120
Strontium	-	4,700	240	-	-
Mercury	0.03	130	-	4,340	-
Nickel	5.4	-	46	-	8.5
Chromium	0.005	-	540	-	108,000

* Water Quality Criteria - Report of the National Technical Advisory Committee to the Secretary of the Interior, Federal Water Pollution Control Administration, April 1968.

** Micrograms per liter.

1/ Texas Water Quality Board Data - February 1969.

2/ Federal Water Quality Administration Data - November 1970.

Significant quantities of chlorinated hydrocarbon compounds ranging to over 70 micrograms per kilogram (μg/kg) were observed in the Houston Ship Channel and Galveston areas. No chlorinated hydrocarbons were detected in sediments from Trinity Bay, an area which does not presently receive measurable quantities of municipal or industrial waste discharge. All areas exhibited significant quantities of cadmium, tin, and lead in sediment samples. Concentrations were 0.31 milligrams per gram (mg/g) for cadmium; 0.62 mg/g of tin; and 0.93 mg/g of lead. Mercury concentrations in sediments from the Houston Ship Channel were as high as 2,100 milligrams per kilogram (mg/kg).

Bioassays conducted on Houston Ship Channel water indicate that concentrations of toxic compounds are three times greater than levels which could be tolerated for normal algal growth[2/]. The natural biota of Galveston Bay have been severely damaged by the discharge of toxic wastes, primarily in the Houston Ship Channel. The diversities, numbers, and weights of fish, shrimp, and crabs as well as the diversities of phytoplankton and benthic animals were very low at Morgan Point near the mouth of the Houston Ship Channel and increased in the Bay in proportion to distance from the channel. Fish collected in upper Galveston Bay were generally very small, and those collected at Morgan Point "were in poor physical

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2/ Copeland, B. J., and W. G. Fruh, Ecological Studies of Galveston Bay, Final Report to the Texas Water Quality Board - Contract IAC (68-69), 408, 1969.

condition. A great many were missing caudal fins and some were also missing filamentous portions of pectoral and pelvic fins." Some were blinded with hard white crusts covering their eyes.

Oyster samples were obtained from both approved and prohibited shellfishing areas in Galveston Bay during November 1970, and analyzed for metals content. These data are presented in Table V-5. Although substantial data are available on occurrence of metals in oysters generally, little or no evaluation of these concentrations has been presented concerning acute and chronic toxic levels. The hazard associated with concentrations of heavy metals and other toxic substances has not yet been firmly established by the appropriate regulatory agencies. Specific numerical criteria which signify levels of acute and chronic toxicity should be established as soon as possible.

D. OIL AND PETROCHEMICAL RESIDUES

The Texas Water Quality Requirements stipulate that all waters be "substantially free" of oil. A consistent condition of oil pollution prevails in the Galveston Bay System due to discharges of oil to the Houston Ship Channel as well as the prevalence of the petroleum related industries and vessel traffic. Oil slicks are commonplace in the Channel and are frequently observed in Galveston Bay. During 1968, 65 incidents of pollution from vessels and shore facilities were investigated by the United States Coast Guard.

TABLE V-5

METALS CONCENTRATIONS IN OYSTERS FROM GALVESTON BAY[1/]

NOVEMBER 12, 1970
(MICROGRAMS PER GRAM - WET WEIGHT)

Parameter	Station No. 1	Station No. 2	Station No. 3	Station No. 4a	Station No. 5	Station No. 6	Station No. 7
Zinc	> 35.30	> 39.70	20.46	26.12	21.58	20.26	22.87
Copper	8.24	9.52	5.06	4.79	4.13	7.80	5.23
Cadmium	.41	< .15	< .15	< .15	< .15	< .15	< .15
Lead	< .30	< .30	< .30	< .30	< .30	< .30	< .30
Chromium	< .07	< .07	< .26	< .07	.27	.42	.16
Mercury	.008	.062	.028	.040	.030	.045	.007
Arsenic	< .30	< .30	< .30	< .30	.47	< .30	< .30
Boron	.87	1.65	.66	.58	.78	.38	.76
Phosphorus	270	258	102	225	185	102	196
Iron	14.71	12.30	4.63	7.34	5.55	5.93	13.10
Molybdenum	.47	1.32	1.51	1.57	1.01	.99	.29
Manganese	1.18	.67	.36	.70	.47	.50	.83
Aluminum	21.77	17.84	8.51	13.50	12.33	16.51	25.10
Beryllium	< .0015	< .0015	< .0015	< .0015	< .0015	< .0015	< .0015
Silver	.25	< .015	< .015	< .015	< .015	< .015	.11
Nickel	.24	.75	< .15	.37	< .15	< .15	.25
Cobalt	< .15	< .15	< .15	< .15	< .15	< .15	< .15
Vanadium	< .30	< .30	< .30	< .30	< .30	< .30	< .30
Barium	.20	.03	.04	.15	.07	.06	.15
Strontium	1.53	1.65	1.72	1.80	5.92	3.45	2.40

[1/] See Figure V-11 for sampling locations.

Oil pollution in shellfish producing areas can cause heavy mortality in oysters[3/]. Oyster samples collected from open and closed areas in Galveston Bay in November 1970 were analyzed for oil and hydrocarbon residues at the Woods Hole Oceanographic Institution. Oysters from approved harvesting areas had concentrations of 26 parts per million (ppm) and 23 ppm. The sample from the conditionally approved area had 30 ppm of residues. Oyster tissue from a closed area near Morgan Point at the mouth of the Houston Ship Channel was grossly contaminated as evidenced by the hydrocarbon concentration of 237 ppm. The hydrocarbon residues were not generated by the oysters themselves but were derived from petroleum wastes. The distribution of hydrocarbon residues in all oyster tissues was similar, indicating the same sources of contamination. These residues represent a health hazard for consumption of oysters taken from Galveston Bay, which is directly attributable to the discharge of industrial waste from petrochemical and other related industries; leakage from oil well pumping taking place in the Bay; and from vessel pollution. Based on the concentrations observed in the oyster tissues, the Houston Ship Channel is the major source of these residues to Galveston Bay.

The State of Massachusetts closed West Falmouth Harbor to shellfish harvesting after a September 1969 oil spill. The area of closure

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[3/] McKee, J. E., and H. W. Wolf, Water Quality Criteria, Second Edition, State Water Quality Control Board, Sacramento, California, Publication No. 3-A, 1963.

was extended during 1970 due to the persistence of residues in shellfish, ranging from 4.0 ppm to 126 ppm[4/]. In the closed section of West Falmouth Harbor, residues in shellfish ranged from 4.0 ppm to 12.0 ppm. The control shellfish sample from an uncontaminated area had a concentration of 1.7 ppm. Concentrations of hydrocarbons in shellfish from approved harvesting areas in Galveston Bay are from two to six times greater than observed in closed areas of West Falmouth Harbor.

Very slight amounts of oil or petroleum products in bays and estuaries have been found to impart an oil or kerosene flavor to oyster, clams, and mussels, making them unmarketable. Numerous industries discharge oil and grease to the Houston Ship Channel and Galveston Bay, as determined from permits issued by the Texas Water Quality Board.

Oysters from Galveston Bay were analyzed for aesthetic acceptability by means of odor tests conducted on samples collected in November 1970. The subjective judgments of a panel of judges were analyzed statistically to determine the probability of true odor conditions. Odors were rated on a scale ranging from seven (no odor) to one (very extreme odor). Because some of the oysters had been collected from closed areas, no taste tests were performed.

Oysters collected from East Bay were used as control or reference samples. These were the only oysters that did not have a

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[4/] Blumer, M., et al, The West Falmouth Oil Spill, Woods Hole Oceanographic Institution, Reference No. 70-44, September 1970.

strong odor. Raw oysters from this area received odor scores of 4.8 and 4.9 on the seven-point scale, and roasted oysters were rated 5.5 by the panelists (Table V-6).

Raw oysters near the mouth of the Houston Ship Channel were rated a low 3.1 by the panel, and were characterized by petroleum odors. Oysters collected near the center of the Galveston Bay-Trinity Bay area were given a very low rating of 2.9 and emitted strong odors of sewage.

Oysters rated 3.8 and 4.0 on the odor scale were taken from Stations 3 and 5 in the open area of Red Fish Reef (Figure V-11). Oysters rated 4.0 were obtained from Station 6 in the closed area. Oysters collected from the open area of Spoonbill Reef (Station 7) had nearly acceptable odors, and were rated 4.5 and 5.3 by the testing panel. The text of the report covering the odor examinations is provided in Appendix B.

From these tests it is concluded that oysters inhabiting waters of Galveston Bay acquire unacceptable odors, and the degrees of these odors are dependent upon proximity to the Houston Ship Channel.

E. DISSOLVED OXYGEN

The Galveston Bay Study data show that dissolved oxygen (DO) criteria established for the Houston Ship Channel are being violated consistently. From Morgan Point to the San Jacinto Monument, the DO levels are below the criterion of 4.0 mg/l more than 60 percent of the time. Values in the surface layer range from zero to greater

TABLE V-6

EVALUATION OF GALVESTON BAY OYSTER MEATS FOR ODOR

Judge	Sample Ref.	1	2	3	4a	5	6	7
Raw Oysters								
1	4.0	5.0	4.0	2.0	4.0	4.0	4.0	5.0
2	4.5	4.5	3.5	1.5	2.0	1.5	2.5	4.0
3	5.0	6.0	4.5	4.5	5.0	4.5	6.0	6.0
4	6.0	6.0	2.0	5.0	2.0	5.0	7.0	4.0
5	4.0	4.0	2.0	4.0	2.0	4.0	2.0	5.0
6	5.0	4.0	2.0	6.0	2.5	5.0	2.5	3.0
Total	28.5	29.5	18.5	23.0	17.5	24.0	24.0	27.0
Average	4.8	4.9	3.1	3.8	2.9	4.0	4.0	4.5
Roasted Oysters								
1	6.0	-	-	5.0	-	5.0	-	6.0
2	5.0	-	-	4.0	-	4.0	-	5.0
3	5.0	-	-	5.0	-	3.0	-	5.0
4	4.0	-	-	4.0	-	6.0	-	6.0
5	7.0	-	-	4.0	-	5.0	-	4.0
6	6.0	-	-	1.0	-	4.0	-	6.0
Total	33.0	-	-	23.0	-	27.0	-	32.0
Average	5.5	-	-	3.8	-	4.5	-	5.3

than 7 mg/l from the San Jacinto Monument to the Turning Basin. In the Turning Basin area and from the San Jacinto Monument to the Turning Basin, the DO criteria of 2.0 mg/l and 1.5 mg/l, respectively, for these reaches are being violated more than 85 percent of the time. Dissolved oxygen is generally less than 1.0 mg/l. The DO levels in the San Jacinto River tidal area are violated about 30 percent of the time.

In Galveston Bay west of the Ship Channel, the DO criterion of 5.0 mg/l is met about 95 percent of the time except near Morgan Point where the standard is being violated more than 35 percent of the time. Dissolved oxygen at this location is less than 4.0 mg/l at least 30 percent of the time.

The DO levels in the Trinity Bay area and West Bay east of Carancahua Reef meet the established DO criterion of 5.0 mg/l 95 percent of the time. The levels range from less than 2.0 mg/l to more than 15.0 mg/l in Trinity Bay and less than 3 mg/l to more than 10 mg/l in West Bay.

A criterion of 6.0 mg/l has been established for the remainder of the system. This level was met about 80 percent of the time, with values ranging from less than 4 mg/l to greater than 12 mg/l. The DO levels in thé Gulf of Mexico must meet a criterion of 7.0 mg/l. Observed values in this zone range from 5.0 mg/l to more than 9 mg/l.

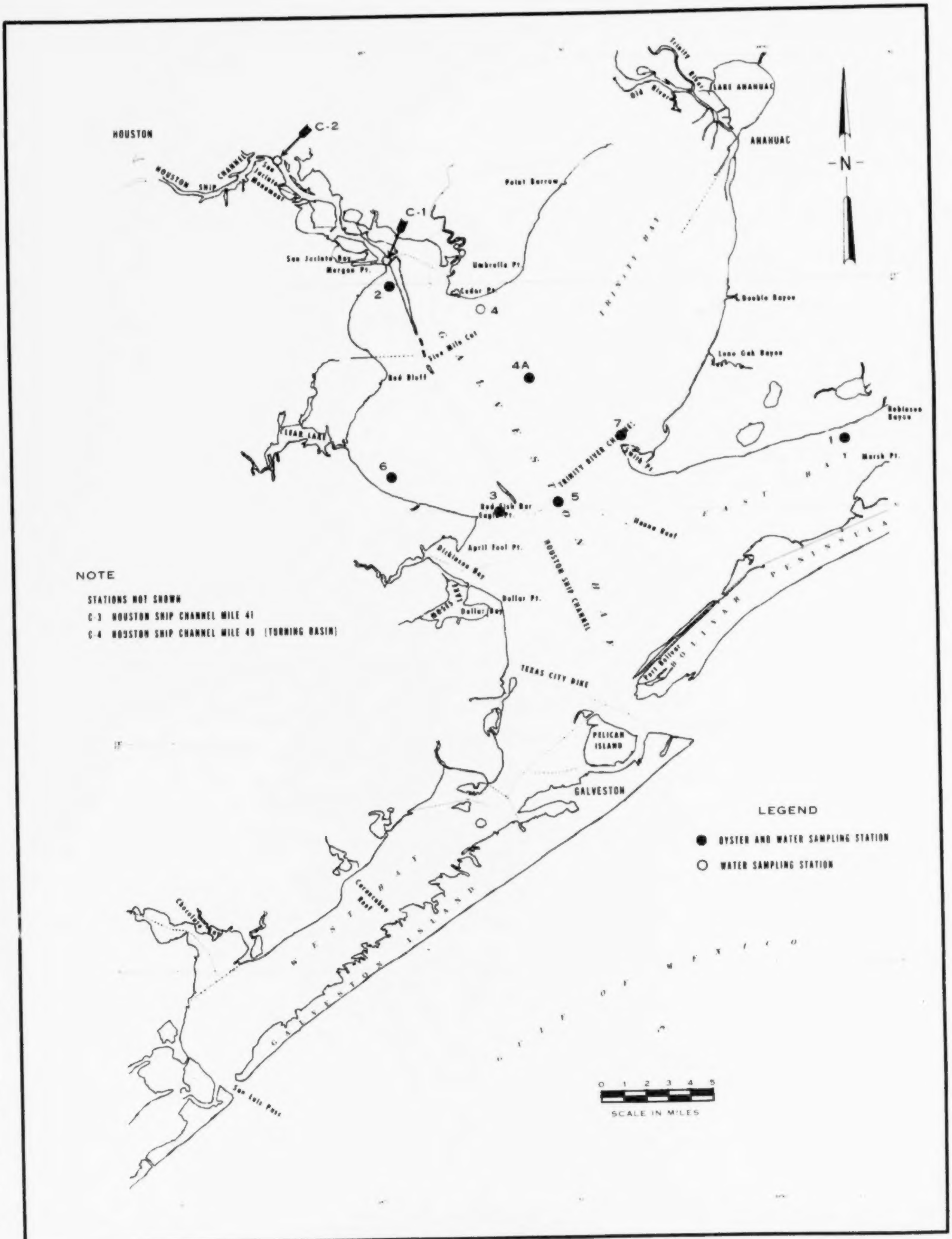
HOUSTON
C-2
HOUSTON SHIP CHANNEL
San Jacinto Monument
C-1
San Jacinto Bay
Morgan Pt.
Point Barrow
Umbrella Pt.
Cedar Pt.
TRINITY BAY
Trinity River
Old River
LAKE ANAHUAC
ANAHUAC
N
Double Bayou
Lone Oak Bayou
Robinson Bayou
Marsh Pt.
EAST BAY
Five Mile Cut
Red Bluff
CLEAR LAKE
GALVESTON BAY
TRINITY RIVER CHANNEL
Smith Pt.
Red Fish Bar
Eagle Pt.
Hanna Reef
April Fool Pt.
Dickinson Bay
MOSES LAKE
Dollar Pt.
Dollar Bay
HOUSTON SHIP CHANNEL
TEXAS CITY DIKE
BOLIVAR PENINSULA
Port Bolivar
PELICAN ISLAND
GALVESTON
WEST BAY
Carancahua Reef
Chocolate Bay
GALVESTON ISLAND
San Luis Pass
GULF OF MEXICO
1
2
3
4
4A
5
6
7
NOTE
STATIONS NOT SHOWN
C-3 HOUSTON SHIP CHANNEL MILE 41
C-4 HOUSTON SHIP CHANNEL MILE 49 (TURNING BASIN)
LEGEND
● OYSTER AND WATER SAMPLING STATION
○ WATER SAMPLING STATION
0 1 2 3 4 5
SCALE IN MILES

Figure V - 11 Water and Oyster Sampling Locations - FWQA Reconnaissance Survey, November 1970

F. BIOCHEMICAL OXYGEN DEMAND

Biochemical oxygen demand (BOD) is a measure of the biologically oxidizable organic material in a wastewater. It theoretically represents the dissolved oxygen consumed by microbial life while assimilating and oxidizing the organics in the waste. The five-day BOD data collected by the Galveston Bay Study for the period July 1968 through June 1970 were evaluated for compliance with the Texas Water Quality Standards which specify BOD averages calculated over a one-year period.

In the Gulf of Mexico at Galveston the BOD criterion of 1.0 mg/l was exceeded 100 percent of the time with yearly averages ranging from 1.8 to 4.1 mg/l. Single BOD observations ranged from less than 1.0 mg/l to 13 mg/l in this zone.

The BOD criteria in the Houston Ship Channel are 7.0, 5.0 and 2.0 mg/l (yearly average) for various zones. These averages were exceeded 100 percent of the time with averages ranging from 4.6 mg/l to 20.8 mg/l. Single BOD observations ranged from 50 mg/l to less than 1.0 mg/l. The BOD criterion established for the Ship Channel from Morgan Point to the San Jacinto Monument (2.0 mg/l) is incongruous with the criteria set for immediately adjacent zones, i.e., Ship Channel to the Turning Basin (5.0 mg/l) and Galveston Bay west of the Ship Channel (6.0 mg/l). This is particularly apparent since BOD exceeds 6.0 mg/l from Morgan Point to the Monument 100 percent of the time although the applicable value is 2.0 mg/l.

A summary of BOD observations compared to required criteria in the remainder of the Galveston Bay system is presented in Table V-7.

The BOD parameter is not indicative of the actual organic pollution present, since the toxicity or growth limiting action of many of the industrial wastes entering Galveston Bay and its tributaries tends to inhibit oxidation of organic material. Depending upon the dilution employed, there was wide variation in BOD values observed in the same sample. This effect was most pronounced in samples collected from the Houston Ship Channel. Where the sample was undiluted, the BOD value was generally less than the BOD of a diluted sample - often by a factor of several hundred percent, thus indicating that toxic or growth inhibiting substances in the sample were preventing satisfaction of organic material. Biochemical oxygen demand is not a satisfactory indicator of the potential effect on water quality caused by most of the waste effluents discharged to the Galveston Bay system. This is particularly true of petrochemical effluents due to the large number of complex waste compounds not immediately susceptible to biological degradation.

TABLE V-7

COMPARISON OF BOD STANDARDS WITH OBSERVED AND AVERAGE VALUES

Zones	Criteria (Annual Average BOD) mg/1	Number Stations in Zone	Percent of Values Exceeding Criterion	Range of BOD Yearly Averages		Range of Single BOD Observation	
				High	Low	High	Low
East Bay	3.0	1	36.8	4.1	2.6	11	1
Galveston Bay East of Houston Ship Channel	4.0	3	23.2	5.3	2.3	12	1
Trinity Bay	5.0	4	32.4	7.2	2.9	19	1
Galveston Bay West of Houston Ship Channel	6.0	15	12.8	9.0	2.1	20	1
West Bay East of Carancahua Reef	3.0	1	18.8	4.5	1.9	14	0
West Bay West of Carancahua Reef	2.5	2	17.6	2.9	1.5	7	1

VI. WASTE SOURCES

The Texas Water Quality Board, in accordance with provisions of the Texas Water Quality Act of 1967, issues effluent permits to municipalities and industries. In the Galveston Bay area, permits have been issued to 141 municipal and domestic waste dischargers and 136 industrial waste dischargers. These discharges, the type of treatment provided, the quantities of waste effluent allowed under the permit, and the water pollution control needs where known, are listed in Tables VI-1 and VI-2. Little or no information is available on actual measurement and characterization of waste discharges.

The total permitted discharge of waste effluent to Galveston Bay and its tributaries, as of 1968, is approximately 779 million gallons per day (MGD) which may contain 583,000 pounds per day of suspended solids, 270,000 pounds per day of BOD, and 1,657,000 pounds per day of chemical oxygen demand (COD). The degree of necessary waste treatment to meet these requirements is not specified in the permits.

Of this total, 92.6 percent of the suspended solids, 85.5 percent of the BOD, and 92.6 percent of the COD are allocated to industrial sources while the remainder is applied to municipal or other domestic effluents. On a flow basis, industrial wastes contribute about 72 percent of the total. The distribution of permitted waste discharge by area is shown in Figures VI-1 through VI-4.

TABLE VI-1-A

MUNICIPAL AND DOMESTIC WASTE DISCHARGES TO THE HOUSTON SHIP CHANNEL ABOVE MORGAN POINT, INCLUDING BAYTOWN AREA[1/]

		PERMITTED DISCHARGE[3/]				
Source	Type of Treatment[2/]	Flow MGD	Susp. Solids #/Day	BOD #/Day	COD* #/Day	Waste Treatment Needs[4/] and Status
Baytown (Bayway Drive)	---	0.700	*117	*117	351	Unknown
Baytown, City of (Craigmont)	---	0.140	23	23	69	Unknown
Baytown, City of (East District)	Primary Chlorination	1.000	167	167	501	Unknown
Baytown, City of (Humble Docks)	Secondary Chlorination	0.560	93	93	279	Complies with permit.
Baytown, City of (West Main)	Secondary Chlorination	2.700	450	450	1,350	Complies with permit.
Beeler, R. F. (Sequoia Estates)	---	0.400	67	67	201	Unknown
Bellaire	None	1.950	325	325	1,075	Unknown
Chambers County (WCID #1)	Secondary Chlorination	0.030	5	6	16	Unknown
Crest Sanitary Corp.	Unknown	0.075	13	13	39	Unknown
Florence, R. G. (Port Haven)	Unknown	0.002	1	1	3	Unknown
Galco Utilities Co.	Unknown	0.108	18	18	54	Unknown
Galena Park (Plant #1)	Secondary No Chlor.	0.700	117	117	351	Unknown
Galena Park (Plant #2)	Secondary No Chlor.	0.100	17	17	**51	Enlarge existing plant.
Harris County (Estex Oaks District)	Secondary Chlorination	1.000	167	*167	501	Meets permit requirements. Houston has requested this plant be transferred to them.
Harris County (WCID-Fondren Road)	Unknown	0.650	108	108	324	Unknown
Harris County (FWSD #8)	Secondary Chlorination	0.700	117	117	351	Unknown
Harris County (FWSD #47)	Secondary Chlorination	0.600	100	200	300	Unknown
Harris County (FWSD #48-1)	---	0.220	37	37	111	Unknown
Harris County (FWSD #48-2)	---	0.210	35	35	105	Unknown
Harris County (FWSD #78)	---	0.100	17	17	51	Unknown
Harris County (WCID #1)	Secondary Chlorination	0.500	83	83	249	Unknown
Harris County (WCID #21)	Secondary Chlorination	0.850	142	142	426	In compliance. No needs.
Harris County (WCID #36)	Secondary Chlorination	0.350	58	58	174	No needs.
Harris County (WCID #69)	Secondary Chlorination	0.565	94	94	282	Plant remodeling required. Does not comply with permit.
Harris County (WCID #70-1)	---	0.050	7	7	21	Unknown
Harris County (WCID #70-2)	---	0.300	40	40	120	Unknown

TABLE VI-1-A (Continued)

MUNICIPAL AND DOMESTIC WASTE DISCHARGES TO THE HOUSTON SHIP CHANNEL ABOVE MORGAN POINT, INCLUDING BAYTOWN AREA 1/

		PERMITTED DISCHARGE 3/				
Source	Type of Treatment 2/	Flow MGD	Susp. Solids #/Day	BOD #/Day	COD* #/Day	Waste Treatment Needs 4/ and Status
Harris County (WCID #73)	---	0.300	40	40	120	Unknown
Harris County (WCID #74)	Secondary Chlorination	0.250	42	42	126	Unknown
Harris County (WCID #78)	Unknown	0.150	20	20	60	Unknown
Harris County (WCID #84)	---	0.400	67	67	201	Unknown
Harris County (WCID #90)	Unknown	0.350	58	58	174	Unknown
Harris County (WCID #93)	Secondary Chlorination	0.700	117	117	351	Will connect to Houston treatment facilities.
Harris County (WCID #94)	Unknown	1.000	167	167	501	In compliance with permit 1970.
Harris County (WCID #95)	Secondary Chlorination	0.325	54	54	162	Unknown
Houston, City of (Water Treatment Plt.)	---	0.020	*3	*1	3	Unknown
Houston, City of (Almeda Plaza)	Secondary Chlorination	0.880	147	147	541	Enlarge existing plant.
Houston, City of (Chadwick Manor)	Secondary No Chlor.	0.056	9	9	27	Unknown
Houston, City of (Chatwood Plant)	Secondary Chlorination	0.276	127	101	303	Construct or improve outfall.
Houston, City of (Chocolate Bayou Plt.)	Secondary Chlorination	1.550	259	259	777	Meeting permit requirements.
Houston, City of (Clinton Park)	Secondary Chlorination	0.750	125	125	375	In compliance with permit.
Houston, City of (Cole Creek Manor)	Secondary Chlorination	0.300	50	50	150	Unknown
Houston, City of (Easthaven)	Unknown	0.214	36	36	108	Unknown
Houston, City of (Fontaine Place Subdivision)	Secondary Chlorination	0.280	163	135	405	Construction or improvement of outfall.
Houston, City of (Forest West)	Unknown	0.300	50	50	150	Unknown
Houston, City of (Gulf Palms Plt.)	Secondary No. Chlor.	0.180	95	48	144	Unknown
Houston, City of (Gulfway Terrace)	Secondary Chlorination	0.135	73	48	144	Unknown
Houston, City of (Harris Co. #34)	Secondary Chlorination	0.300	50	50	150	Unknown
Houston, City of (Internat'l. Arpt.)	---	0.200	33	33	**99	Unknown
Houston, City of (Lake Forest Plt.)	Secondary Chlorination	0.175	70	38	114	Unknown
Houston, City of (Longwood Subdivision)	Secondary Chlorination	0.021	4	4	12	Construction or improvement of outfall.
Houston, City of (New Homestead)	---	0.880	147	147	441	Currently meeting permit requirements.

TABLE VI-1-A (Continued)

MUNICIPAL AND DOMESTIC WASTE DISCHARGES TO THE HOUSTON SHIP CHANNEL ABOVE MORGAN POINT, INCLUDING BAYTOWN AREA[1]

Source	Type of Treatment[2]	PERMITTED DISCHARGE[3] Flow MGD	Susp. Solids #/Day	BOD #/Day	COD* #/Day	Waste Treatment Needs[4] and Status
Houston, City of (Northeast Dist.)	None	2.000	334	334	1,002	Construct secondary treatment plant.
Houston, City of (Northside Plt.)	Secondary No Chlor.	55.000	9,174	9,174	27,522	Not in compliance with permit.
Houston, City of (Northwest Plt.)	Unknown	4.000	673	673	2,019	Unknown
Houston, City of (Red Gully Plant)	---	0.300	50	50	150	Unknown
Houston, City of (Sims Bayou)	Secondary No Chlor.	48.000	8,006	8,006	24,018	Unknown
Houston, City of (Southwest Plant)	Secondary Chlorination	15.000	2,502	2,502	7,506	Enlarge existing plant.
Houston, City of (West Dist. Plt.)	Secondary Chlorination	6.000	1,002	1,002	3,006	Plant enlargement underway. Current quality in compliance.
Houston, City of (FWSD #23)	Secondary Chlorination	1.250	209	209	627	Enlarge plant. Construct or improve interceptors and outfalls.
Houston, City of (WCID #17)	---	0.750	494	125	375	Plant is to be enlarged to serve as a Regional Treatment System.
Houston, City of (WCID #20)	Secondary Chlorination	0.125	21	21	63	Construction or improvement of outfall.
Houston, City of (WCID #32)	Secondary Chlorination	0.750	125	125	375	Unknown
Houston, City of (WCID #34)	Secondary Chlorination	0.136	50	31	124	Unknown
Houston, City of (WCID #39)	Secondary Chlorination	0.522	305	135	405	Plant to be abandoned and flow diverted to another plant.
Houston, City of (WCID #42)	Secondary Chlorination	0.436	469	262	786	Unknown
Houston, City of (WCID #44-1)	Secondary Chlorination	0.250	261	200	600	Unknown
Houston, City of (WCID #44-2)	Secondary Chlorination	0.088	17	15	45	Unknown
Houston, City of (WCID #44-3)	Secondary Chlorination	0.700	490	403	1,209	Unknown
Houston, City of (WCID #47-1)	Secondary Chlorination	0.384	702	90	270	Construct or improve outfall.
Houston, City of (WCID #47-2)	Secondary Chlorination	0.384	160	86	258	Unknown
Houston, City of (WCID #51)	Secondary Chlorination	1.253	209	209	627	Unknown
Jacinto City	Secondary Chlorination	1.200	*320	320	960	Plant presently overloaded but meeting permit requirements.
Jersey Village	Unknown	0.066	11	11	33	Unknown
Jetro Lumber and Building Co.	---	0.012	2	2	6	Unknown
Katy, City of	Secondary Chlorination	0.280	*48	*48	144	Unknown
Mayflower Investment Company	---	0.500	83	83	249	Unknown

TABLE VI-1-A (Continued)

MUNICIPAL AND DOMESTIC WASTE DISCHARGES TO THE HOUSTON SHIP CHANNEL ABOVE MORGAN POINT, INCLUDING BAYTOWN AREA[1/]

Source	Type of Treatment[2/]	PERMITTED DISCHARGE[3/] Flow MGD	Susp. Solids #/Day	BOD #/Day	COD* #/Day	Waste Treatment Needs[4/] and Status
Memorial Villages Water Authority	Unknown	1.500	250	250	750	Plant currently meeting permit requirements.
Morgan Point, City of	---	0.100	17	17	51	Unknown
Nitsch, A. J. (Durkee Manor)	---	0.250	42	42	126	Unknown
Oak Glen Building Corp. (North Terrace)	---	0.300	40	40	120	Unknown
Oakwide Water Co.	Unknown	0.245	41	41	123	Unknown
Pace Setter, Inc. (Imp. Val.)	---	0.300	50	50	150	Unknown
Pasadena, City of (Deepwater Plant)	Secondary Chlorination	1.000	167	167	501	Unknown
Pasadena, City of (Northside Plant)	Secondary Chlorination	5.000	834	834	2,502	Not in compliance. Plant overloaded. Present volume 6.400 MGD.
Piney Point Village	Secondary No Chlor.	1.000	2,002	1,668	4,904	Unknown
Powell, C. L. (Nursing Home #2)	---	0.004	1	1	3	Unknown
Royalwood Municipal Utility District	Unknown	0.100	17	17	51	Unknown
Southern San. Corp.	---	0.350	58	58	174	Unknown
South Houston, City of	Secondary Chlorination	0.640	283	283	849	Enlarge existing plant.
Southside Place, City of	Secondary Chlorination	0.216	36	36	108	Unknown
Texas Highway Dept. (Interstate 10 Rest Stop)	---	0.010	2	2	6	Unknown
Turkey Creek Imp. District	Unknown	0.750	125	125	375	Unknown
Western Trails Prop., Inc.	Unknown	0.250	42	42	126	Unknown
West Road Imp. District	---	0.550	92	92	**276	In compliance with permit.
West University Place, City of	Secondary Chlorination	1.000	167	167	501	In compliance with permit.
White Oaks Develop. Co.	Unknown	0.050	7	7	21	Unknown
Young, Mrs. Mabel C.	---	0.098	16	16	48	Unknown

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* Estimated Value.

** True Value.

1/ Water Quality Standards for Zones 0904, 0905, and 0906 Apply - See Table V-1.

2/ Information from the FWQA STORET Inventory - Printout Date November 1970.

3/ Data from "Permitted Discharge Quantities - Buffalo Bayou and the Houston Ship Channel" compiled by FWQA, South Central Region.

4/ Information from FWQA STORET Inventory - Printout Date November 1970 and/or "Summary of Waste Discharges into the Houston Ship Channel in excess of 500,000 GPD." The latter document supplied by FWQA, South Central Region.

TABLE VI-1-B

MUNICIPAL AND DOMESTIC WASTE DISCHARGES TO GALVESTON BAY

Source	Type of Treatment[2]	PERMITTED DISCHARGE[3]				Waste Treatment Needs[4] and Status
		Flow MGD	Susp. Solids #/Day	BOD #/Day	COD* #/Day	
Discharges to Galveston Bay or Tributaries. Morgan Point to Eagle Point (Includes Clear Lake Area) Zone 1104[1]						
Baycliff MUD	Secondary Chlorination	1.000	167	167	501	Unknown
Bayview MUD	Secondary Chlorination	0.250	42	42	126	Unknown
Clear Lake Utilities, Inc.	Unknown	0.250	42	42	126	Unknown
Clear Lake Water Authority	Secondary Chlorination	2.250	375	375	1,125	Unknown
Deer Park, City of -- South	Secondary Chlorination	0.700	117	117	351	Unknown
Ellington Air Force Base	Unknown	0.350	58	58	174	Unknown
Friendswood, City of	Secondary Chlorination	0.570	87	87	261	No needs.
Galveston County (WCID #12)	Unknown	0.425	71	71	213	Unknown
Harris County (Clear Woods Dist.)	Unknown	0.500	83	83	249	Unknown
Harris County (WCID #50)	Unknown	0.500	83	83	249	Unknown
Harris County (WCID #56)	Secondary Chlorination	0.580	97	97	291	Unknown
Harris County (WCID #75)	Secondary Chlorination	0.150	25	25	75	Unknown
Harris County (WCID #81)	Secondary Chlorination	0.250	42	42	126	Unknown
Harris County (WCID #83)	Secondary Chlorination	1.350	225	225	675	Unknown
Houston, City of (Gulf Meadows)	None	0.155	26	26	78	Enlarge Existing plant.
Houston, City of (Sagemont MUD)	Unknown	2.000	334	334	1,002	Unknown
Houston, City of (WCID #53)	Secondary Chlorination	0.368	61	61	183	Unknown
Houston, City of (WCID #62)	Secondary Chlorination	0.280	47	47	141	Unknown
Lagoon Utility Co.	Unknown	0.070	12	12	36	Unknown
La Porte, City of	Secondary Chlorination	0.723	121	121	363	No needs
League City	Secondary Chlorination	1.500	250	250	750	Unknown
Pasadena, City of (Golden Ac.)	Secondary Chlorination	0.400	67	67	201	Unknown
San Jacinto Jr. College	Unknown	0.128	21	21	63	Unknown
Seabrook, City of	Secondary Chlorination	2.500	417	417	1,251	No needs
Shoreacres, City of	Unknown	0.235	39	39	117	Unknown

TABLE VI-1-B (Continued)

MUNICIPAL AND DOMESTIC WASTE DISCHARGES TO GALVESTON BAY

Source	Type of Treatment 2/	PERMITTED DISCHARGE 3/ Flow MGD	Susp. Solids #/Day	BOD #/Day	COD* #/day	Waste Treatment Needs 4/ and Status
Webster, City of	Secondary Chlorination	0.400	67	67	201	No needs.
Discharges to Galveston Bay and Tributaries, Eagle Point to Galveston (includes Dickinson Bayou and Texas City) Zone 1104 1/						
Galveston, City of (Airport)	Unknown	0.360	60	60	180	Unknown
Galveston, City of (Main Plant)	Unknown	6.400	1,068	1,068	3,204	Construct or improve interceptors, outfalls, and pumping station.
Galveston, City of (Teichman Point)	Unknown	0.050	8	8	24	Construct or improve interceptor.
Galveston, County (WCID #1)	Secondary No Chlor.	1.700	284	284	852	Unknown
Sunmeadow MUD	Unknown	0.014	2	2	6	Unknown
Texas City, City of	Secondary Chlorination	5.000	834	834	2.402	No needs.
Other Areas of Galveston Bay, Trinity Bay and Tributaries Zone 1103 1/						
Anahuac, City of	None	0.404	67	67	201	Construction secondary plant, outfall, and pumping station.
Dayton, City of	Secondary Chlorination	0.553	92	92	276	Additional facilities required.
Liberty, City of	Secondary Chlorination	0.692	145	258	774	Unknown
Trinity Bay Cons. District	Unknown	0.400	53	53	159	Unknown
West Bay and Tributaries Zones 1105 & 1106 1/						
Alvin, City of	Secondary Chlorination	3.750	626	626	1,878	Unknown
Brazoria County (WCID #4)	Unknown	0.160	27	27	81	Unknown
Fabulous Flamingo Isles	Unknown	0.200	33	33	99	Unknown
Galveston County (WCID #8)	Unknown	0.040	7	7	21	Unknown
Hitchcock, City of	Secondary Chlorination	0.300	50	50	150	Unknown
LaMarque, City of	Secondary Chlorination	1.900	555	317	1,551	Construction or improvement of outfall.
Oak Manor MUD	Unknown	0.050	8	8	24	Unknown
Robert E. Pine Utility Co.	Unknown	0.049	8	8	24	Unknown

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* Estimated values

1/ Water Quality Standards for this zone - See Table V-1.

2/ Information from the FWQA STORET Inventory - Printout Date November 1970.

3/ Data from "Permitted Discharge Quantities - Galveston Bay Area" compiled by FWQA South Central Region.

4/ Information from FWQA STORET Inventory - Printout Date November 1970 and/or "Summary of Waste Discharges into the Houston Ship Channel in excess of 500,000 GPD." The latter document supplied by FWQA, South Central Region.

TABLE VI-2-A

WASTE DISCHARGES FROM PETROLEUM, CHEMICAL, PLASTICS, AND RUBBER INDUSTRIES TO THE HOUSTON SHIP CHANNEL OR ITS TRIBUTARIES ABOVE MORGAN POINT INCLUDING THE BAYTOWN AREA[1]

	PERMITTED DISCHARGE[2]					
Name	Flow MGD	Oil & Grease mg/l	Susp. Solids #/day	BOD #/day	COD #/day	Waste Treatment Needs and Status[3]
Amerada Petroleum Corp	0.028	--	*1	*1	*3	Unknown
Armour Agriculture Chemical Co.	0.664	--	2,011	*111	30	Unknown
Ashland Chemical Co. (Highland Chemical Co.)	1.380	20	806	575	2,302	Preaeration-sedimentation-temperature.
Atlantic Richfield Co. (11 outfalls)	8.950	4 to 135	5,355	9,347	*27,041	Biological treatment-domestic sewer hook-up to city to be completed 12/70.
Best Fertilizer Co.	0.007	10	4	1	9	Unknown
Celanese Plastic Co.	0.425	5	213	53	195	In compliance with permit requirements.
Cook Paint and Varnish Co.	0.080	Trace	4	*13	*39	Unknown
Crown Central Petrol. Corp. (4 outfalls)	1.600	10 to 90	2,834	3,686	11,058	Oil separation and biological treatment to be completed 1972.
Diamond Shamrock Corp. (7 outfalls)	0.500	--	*83	*83	*249	Biological treatment required.
Diamond Shamrock Corp. at Deer Park (6 outfalls)	149.250	10	124,474	35,458	211,044	Heavy Metal (Hg) removal, pH control, solids containment. Engineering underway.
Distillate Production Corp.	0.050	--	*8	*8	*24	Unknown
Dixie Chemical Co.	0.058	0.5	8	10	73	Unknown
Eddy Refining Co.**	0.001	0.3	1	1	1	Unknown
E. I. DuPont deNemours (2 outfalls)	4.312	25 15	1,257	1,795	7,192	Oil skimmer and aerated lagoon. Engineering in progress.
Enjay Chemical Co.	0.200	20	150	150	584	Unknown
Ethyl Corp. (2 outfalls)	26.000	3	4,337	4,337	6,505	Treatment facilities were modified to improve quality of effluent.
Goodyear Tire and Rubber Co. (Houston plant)	2.535	25	1,570	1,257	3,145	Settling and biological treatment. Lawsuit pending.
Gulf Oil Corp.	0.900	5	150	150	1,501	Unknown
Gulf States Asphalt Co., Inc.	0.150	5	25	13	50	Industry in compliance.
Hess Terminals	0.108	25	90	90	360	Unknown
Hooker Chemical Corp. (3 outfalls)	0.018	5	4	2	17	Unknown
Houston Natural Gas Corp.	1.340[3]	--	Unknown	Unknown	Unknown	Unknown
J. M. Huber Corp.	0.220	10	128	92	367	Unknown
Humble Oil and Refining Co.	25.000	20	14,595	10,425	41,700	Meeting permit requirements
Jefferson Lake Sulfur Co.	0.225	--	0	*1	*3	Unknown
Koppers Co., Inc.	0.008	20	3	3	13	Unknown
The Lubrizol Corp.** (2 outfalls)	1.000	25	834	834	3,336	Oil removal and biological treatment, solids disposal. Construction underway.
Marbon Chemical	0.090	4	2	1	15	No implementation schedule.
Merichem Company (Greens Bayou)	0.225	20	141	141	563	Not in compliance.
Murray Rubber Company	0.010	--	2	2	6	Unknown.

TABLE VI-2-A (Continued)

WASTE DISCHARGES FROM PETROLEUM, CHEMICAL, PLASTICS, AND RUBBER INDUSTRIES TO THE HOUSTON SHIP CHANNEL OR ITS TRIBUTARIES ABOVE MORGAN POINT INCLUDING THE BAYTOWN AREA[1/]

	PERMITTED DISCHARGE[2/]					
Name	Flow MGD	Oil & Grease mg/1	Susp. Solids #/day	BOD #/day	COD #/day	Waste Treatment Needs and Status[3/]
Olin Mathieson Chemical Corp.**	10.145		4,492	950	9,692	Additional oxidation ponds required. To be completed 1971.
Pennsalt Chemical Corp.	0.200	15	58	83	250	Unknown.
Petrolite Corp.-Petreco Corp.	0.002	20	1	1	1	Unknown
Petro Tex Chemical Corp.** (3 outfalls)	4.800	10 to 25	4,003	3,919	15,680	Aeration and solids removal equipment installed.
Phillips Petroleum Co. (Coast Res.)	0.090	--	*15	*15	*45	Unknown
Phillips Petroleum Co. at Pasadena (3 outfalls)	6.920	10	1,630	837	1,365	Sludge dewatering and biological oxidation. Work in progress.
Phosphate Chemicals, Inc. (2 outfalls)	0.455	20 5	218	190	1,897	Unknown
Plastic Applicators, Inc.	0.030	2.7	12	2	10	pH control, holding facilities and chemical treatment. In progress.
Premier Petrochemical Co.**	0.150	--	25	25	*75	pH control and NH_3 removal, addition of aeration required.
Reichhold Chemicals**	0.020	25	17	17	67	Solids and COD removal. No action.
Rohm and Haas Co.** (2 outfalls)	1.800	25	5,789	1,489	10,929	Operational problems with treatment facilities.
S and R Oil Co.	0.036	--	6	6	*18	Unknown
Shell Chemical Co. (2 outfalls)	6.100	25	15,262	5,087	50,874	Present plant overloaded. Expansion to be completed by 3/71.
Shell Oil Co.** (13 outfalls)	5.974	10 to 25	2,616	1,953	9,286	Effluent meets permit requirements.
Signal Oil and Gas Co. (2 outfalls)	2.880	25	1,801	1,201	9,608	Secondary treatment facilities near completion.
Sinclair-Koppers Chemical Co.	0.550	20	413	459	1,376	Company in compliance except for high COD.
Sinclair-Petrochemical, Inc.**	2.660	20	1,553	1,109	4,437	Unknown
Southwest Chemical & Plastic	0.004	14	1	1	2	Unknown
Stauffer Chemical Co.** (Greens Bayou) (2 outfalls)	1.165	10	486	194	194	Unknown
Stauffer Chemical Co.** (South of HSC)	1.000	25	417	167	667	Facilities for pH control near completion.
Superior Oil Co.	0.003	--	1	1	*3	Unknown
Tenneco Manufacturing Co.**	1.000	20	500	834	2,335	Effluent meets permit requirements.
Union Carbide, Linde Div.	0.144	20	60	24	120	Unknown
The Upjohn Co.**	0.580	15	339	242	967	Effluent in compliance with permit requirements.
Velsicol Chemical Corp.**	0.144	25	120	120	480	Unknown

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* Effluent toxic to bacteria - Information from the Houston Ship Channel Survey of Waste Effluents conducted in February 1969. FWQA South Central Region supplied data.

** Estimated values.

1/ Water Quality Standards for zones 0904, 0905, and 0906 apply - see Table V-1.

2/ Data from "Permitted Discharge Quantities - Buffalo Bayou and Houston Ship Channel" compiled by the FWQA, South Central Region.

3/ Data from (a) Summary of Waste Discharges into the Houston Ship Channel in excess of 500,000 GPD and/or (b) Summary of Industrial Waste Needs and/or (c) Summary of Industrial Facilities constructed and/or rehabilitated. The foregoing documents supplied by the FWQA, South Central Region.

TABLE VI-2-B

OTHER INDUSTRIAL DISCHARGES TO THE HOUSTON SHIP CHANNEL OR ITS TRIBUTARIES1/

	PERMITTED DISCHARGES2/					
Name	Flow MGD	Oil & Grease mg/1	Susp. Solids #/day	BOD #/day	COD #/day	Waste Treatment Needs and Status3/
Airport Service Co.	0.004	15	1	1	*3	Unknown
Anchor Hocking Glass Corp.	0.028	15	5	5	50	Unknown
Armco Steel Corp.**	32.464	25	14,346	6,680	52,038	Unknown
Baker Oil Tools, Inc.	0.025	25	13	4	8	Unknown
Baroid Division-Nat. Lead Co.	0.503	10	84	63	627	Unknown
Big Three Weld. Equipment Co.	0.007	--	*1	*1	*3	Unknown
Cameron Iron Works	0.036	50	44	*121	363	Unknown
Dresser Magcobar	0.006	5	1	1	10	Unknown
Dresser Systems, Inc.	0.105	--	18	18	*54	Unknown
Equity Export Corp.	0.002	5	1	1	1	Unknown
General Portland Cement Co.	0.500	--	209	4	24	Unknown
Grief Bros. Cooperage Co.	0.004	2	1	1	7	Unknown
Groendyke Transport	0.001	--	1	1	1	Unknown
Gulf Coast Portland Cement Co.	0.250	25	209	31	104	Unknown
Horton and Horton, Inc. (N. Live Oak)	0.003	--	80	1	*1	Unknown
Horton and Horton, Inc. (Pasadena)	0.001	--	27	*1	*3	Unknown
Houston Light and Power Co.**	0.004	0	1	1	3	Unknown
Houston Light and Power Co. (H. O. Clarke)	0.248	0	33	31	124	Unknown
Houston Light and Power Co. (Deepwater)(5 outfalls)	0.072	0	4,271	4,255	17,016	Unknown
Houston Light and Power Co. (Greens Bayou)	1.120	0	9	93	374	Unknown
Houston Light and Power Co. (T. H. Wharton)	4.800	0	200	240	1,001	Unknown
Hughes Tool Co. (5 outfalls)	0.990	15	143	122	591	Unknown
Ideal Cement Co.**	0.605	15	484	149	734	Effluent in compliance with permit requirements.
John Mecom and Proler Steel Corp.	0.007	--	1	1	*3	Unknown
Lead Products, Inc.	0.035	5	6	3	29	Unknown
Lone Star Cement Corp.	0.151	10	126	14	64	Unknown
Mission Manufacturing Co.	0.150	10	25	25	75	Unknown
National Bisquit Co.	0.002	5	1	1	2	Unknown
National Molasses Co.**	0.001	10	*1	*1	*3	Unknown
Nation Supply Div. Armco	0.112	15	14	19	140	Unknown
Parker Bros. and Co. (Clay Rd.)	0.002	--	*17	*1	*3	Unknown

TABLE VI-2-B (Continued)

OTHER INDUSTRIAL DISCHARGES TO
THE HOUSTON SHIP CHANNEL OR ITS TRIBUTARIES[1/]

	PERMITTED DISCHARGE[2/]					
Name	Flow MGD	Oil & Grease mg/l	Susp. Solids #/day	BOD #/day	COD #/day	Waste Treatment Needs and Status[3/]
Parker Bros. and Co., Inc. (Main)	0.003	--	*1	*1	*3	Unknown
Parker Bros., Inc. (W. Park Plant)	0.001	--	*1	*1	*4	Unknown
Parker Bros. and Co. (Winfield)	0.001	--	*1	*1	*3	Unknown
Philip Carey Corp.	0.040	15	5	7	68	Unknown
Pittsburg Plate Glass Co.	0.160	15	13	13	53	Unknown
Rapid Transit Lines, Inc.	0.025	5	8	5	14	Unknown
Reddy Ice Division Southland Co.	0.014		1	1	1	Unknown
Reed Drilling Tools	0.722	25	482	361	2,108	Unknown
Reliance Universal, Inc.	0.007	1	1	--	2	Unknown
Shaw Tank Cleaning Co.	0.001	13	1	1	*3	Unknown
A. O. Smith Corp.**	0.850	25	425	354	1,418	Effluent meets permit requirements.
Smith-Douglas Co., Inc.	0.043	--	0	*7	*21	Unknown
Smith Industries, Inc.	0.007		*1	*1	*3	Unknown
SMS Industries	0.115	20	67	48	192	Aeration and solids removal. In progress.
Southern Pacific Co. (Englewood)	0.011	1	2	2	18	Unknown
Southern Pacific Railroad (Hardy St.)	0.016	15	5	3	27	Unknown
Southland Paper Mills #1	50.000	10	41,700	41,700	166,800	Solids and color removal. Engineering in progress.
Texas Instrument	0.645[3/]		Unknown	Unknown	Unknown	Effluent complies with permit.
Todd Shipyards	0.008	--	*13	*13	*39	Unknown
Uncle Ben's Inc.	0.167	15	28	28	*84	Unknown
United States Gypsum** (2 outfalls)	0.500	25	417	417	1,668	Aerated lagoon and screening. To be in compliance 12/70.
U.S. Plywood - Champion Papers, Inc. (3 outfalls)	44.000	25	36,696	18,348	146,784	Required biological treatment being constructed.

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* Estimated values.

** Effluent toxic to bacteria - Information from the Houston Ship Channel Survey of Waste Effluents conducted in February 1969. FWQA, South Central Region supplied data.

1/ Water Quality Standards for Zones 0904, 0905, and 0906 apply - see Table V-1.

2/ Data from "Permitted Discharge Quantities - Buffalo Bayou and Houston Ship Channel" compiled by the FWQA, South Central Region.

3/ Data from (a) Summary of Waste Discharges into the Houston Ship Channel in excess of 500,000 GPD and/or (b) Summary of Industrial Waste Needs and/or (c) Summary of Industrial Facilities constructed and/or rehabilitated. The foregoing documents supplied by the FWQA, South Central Region.

TABLE VI-2-C

WASTE DISCHARGES FROM PETROLEUM, CHEMICAL, PLASTICS, AND RUBBER INDUSTRIES TO GALVESTON BAY OR ITS TRIBUTARIES

	PERMITTED DISCHARGE 2/					
Name	Flow MGD	Oil & Grease mg/1	Susp. Solids #/day	BOD #/day	COD #/day	Waste Treatment Needs and Status 3/
Discharges to Galveston Bay or Tributaries - Morgan Point to Eagle Point (includes Clear Lake Area) Zone 1104 1/						
Chemetron Chems.	0.144	2	24	24	96	Meets permit requirements.
Humble Oil and Refinery Co. (Bayport)	0.010	--	2	2	*6	Unknown
Humble Oil and Refinery Co. (Bayport)	9.000		5,292	1,501	15,012	Activated sludge, stabilization basins and aerobic digestion. Construction plans in progress.
Humble Oil and Refinery Co. (Clear Lake)	0.008	--	1	1	*3	Unknown
Lowe Chemical Co.	0.726	--	0	*121	*363	Unknown
Pan American Petroleum Corp.	0.012	--	1	1	*3	Unknown
Retzloff Chemical Co.	0.010	--	2	2	*6	Unknown
Southeast Chemical and Plastic Co.	0.043	--	4	6	*18	Unknown
Discharges to Galveston Bay or Tributaries (Eagle Point to Galveston) (includes Dickinson Bayou and Texas City) Zone 1104 1/						
American Oil Co. at Texas City	13.000	--	3,686	9,649	*28,947	Need extended aeration. Discharge over permit.
Amoco Chemical Corp. (Plant A)	0.370	20	216	154	617	Unknown
The Borden Chemical Corp. near Texas City	0.030	--	8	*4	*29	Need pH control and PO_4 removal.
Chem. Industries Corp.	0.002	--	1	1	*3	Unknown
General Analine and Film Corp. Texas City plant	1.000 3/	--	Unknown	Unknown	Unknown	Aeration and in-plant controls. Present discharge over permit.
Humble Oil and Refinery Co. (Dickinson)	0.003	--	1	1	*3	Unknown
Marathon Oil Co. at Texas City	1.156	25	*1,186	405	1,591	H_2S Stripper and biological treatment.
Mineral Oil Refinery Co.	0.082	--	34	34	*102	Unknown
Monsanto Chemical Co. at Texas City	106.000	--	*224,004	*8,397	*569,589	Oil skimming, clarification, biologically inert plastic pellets spearation.
Pan American Pet. Corp.	0.035	4	6	1	3	Unknown
Texas City Refining Co.	1.440	20	0	973	1,441	Discharge over permit. Biological phenols and flouride removal - in progress.
Union Carbide Chemical Co. at Texas City	10.196	--	4,936	46,391	84,181	Discharge over permit. Construction of treatment facility in progress.
Discharges to Other Areas of Galveston Bay, Trinity Bay or Tributaries Zone 1103 1/						
Texas Gulf Sulfur (Moss Bluff)	4.541	--	*751	*751	*2,251	Unknown
West Bay or Tributaries Zones 1105 and 1106) 1/						
Monsanto Chem. Co. (Chocolate Bayou)	2.900		726	726	*2,175	Increased Biological Capacity required.
Phillips Petroleum Co. (Bayou)	0.437	--	*73	73	*219	Unknown

---

* Estimated values.

1/ See Table V-1 for applicable water quality standards in this zone.

2/ Data from "Permitted Discharge Quantities - Galveston Bay Area," compiled by the FWQA, South Central Region.

3/ Data from (a) Summary of Industrial Waste Needs and/or (b) Summary of Industrial Facilities Constructed and/or Rehabilitated. The foregoing documents supplied by the FWQA, South Central Region.

TABLE VI-2-D

OTHER INDUSTRIAL DISCHARGES TO GALVESTON BAY OR ITS TRIBUTARIES

Name	Permitted Discharge[2]					Waste Treatment Needs and Status[3]
	Flow MGD	Oil & Grease mg/1	Susp. Solids #/day	BOD #/day	COD #/day	
Discharges to Texas City, Galveston and Dickinson Bayou Areas - Zone 1104[1]						
Atchison, Topeka, & Santa Fe Railroad #1	0.004	20	*7	*7	*21	Unknown
Atchison, Topeka, & Santa Fe Railroad #2	0.002	0.0	*3	*3	*9	Unknown
Malone Service Co.	0.010	-	*42	*0	*6	Completely retained.
Texas City Terminal Railroad	0.003	-	1	1	*3	Unknown
Todd Shipyards Corp.	0.032	-	*53	*53	*159	Unknown
Wah Chang Corporation	0.110	-	43	2	11	Chemical treatment and pH control. No compliance date set.
Discharges to West Bay Area Zone 1105[1]						
McGinnes Industries Main Co.	1.000	-	584	417	1,668	Unknown

* Estimated values

[1] See Table V-1 for applicable water quality standards in this zone.

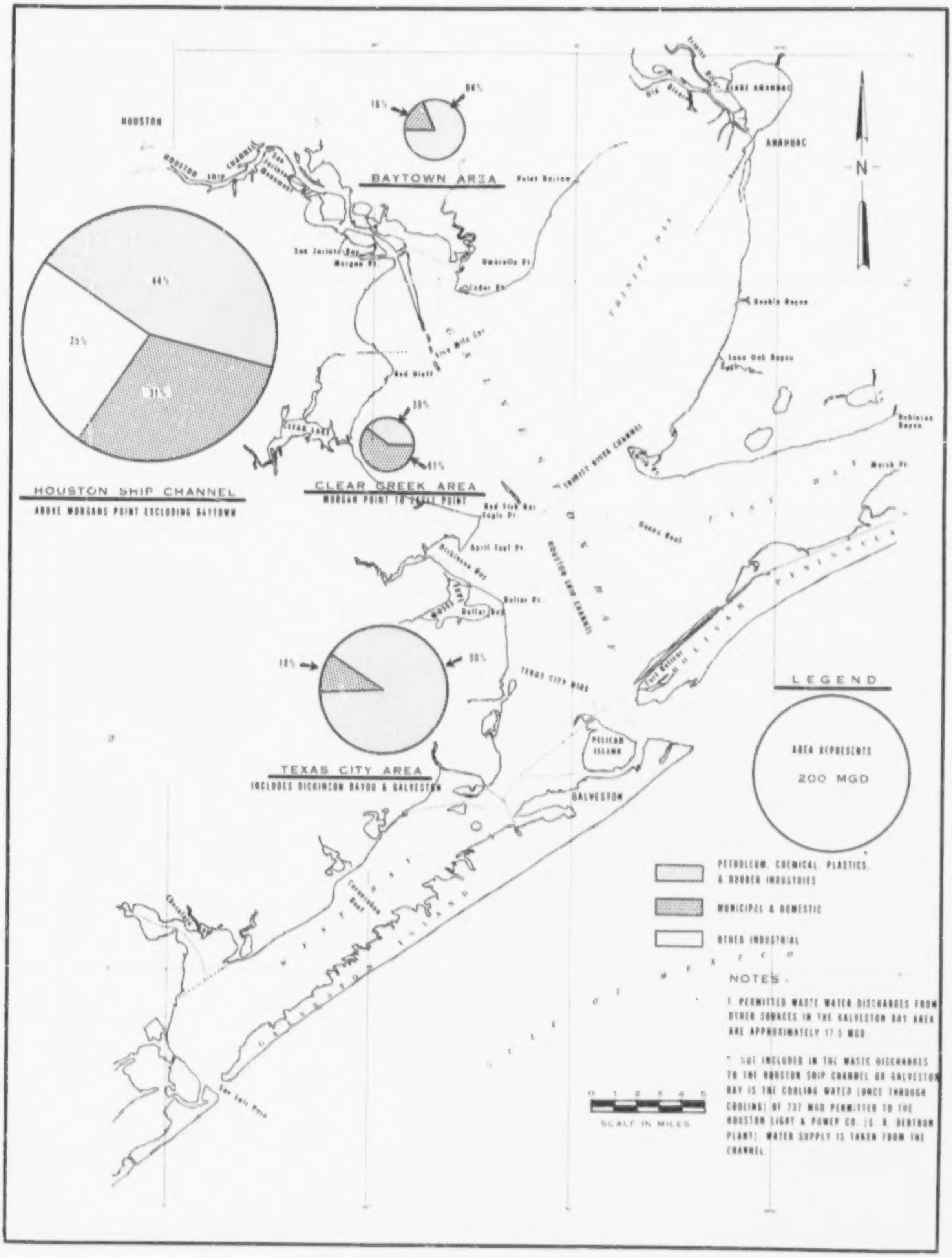
[2] Data from "Permitted Discharge Quantities-Galveston Bay Tributaries", compiled by the FWQA, South Central Region.

[3] Data from (a) Summary of Industrial Waste Needs and/or (b) Summary of Industrial Facilities Constructed and/or Rehabilitated. The foregoing documents supplied by the FWQA, South Central Region.

A. MUNICIPAL AND DOMESTIC WASTE DISCHARGES

Municipal and domestic waste sources are permitted to discharge over 215 MGD containing 39,400 pounds per day of suspended solids, 39,300 pounds per day of BOD and 118,900 pounds per day of COD. The areas where most of this waste is discharged are the Houston Ship Channel and tributaries, Clear Lake, and the Texas City, Galveston, and Dickinson Bayou areas. The Houston Ship Channel area has 90 sources discharging about 172 MGD with 31,500 pounds per day of suspended solids, 31,300 pounds per day of BOD, and 95,200 pounds per day of COD. This represents 80 percent of the waste effluent permitted from domestic sources in Galveston Bay. Clear Lake with 26 sources and Texas City-Galveston-Dickinson Bayou with six sources, discharge 7.5 percent, and 5.6 percent of the total, respectively. The remaining 7 percent is discharged from the Baytown, Trinity Bay, and West Bay areas.

Nearly 144 MGD is discharged from 37 treatment plants by the city of Houston to the Houston Ship Channel or its tributaries. Only eight of these plants have flows greater than one MGD. The two major installations are the Northside plant at 55 MGD and the Sims Bayou plant with 48 MGD. It has previously been demonstrated that the Houston Ship Channel is the major source of coliform pollution contaminating shellfish harvesting areas in Galveston Bay. Most of the permits for municipal sources require disinfection of wastes by chlorination. Neither the Northside nor Sims Bayou plants have chlorination facilities as of January 1971.


HOUSTON
HOUSTON SHIP CHANNEL
San Jacinto Monument
BAYTOWN AREA
16%
84%
Point Barrow
San Jacinto Bay
Morgan Pt.
Umbrella Pt.
Cedar Pt.
Five Mile Cut
Red Bluff
TRINITY BAY
Trinity River
Old River
LAKE ANAHUAC
ANAHUAC
N
Double Bayou
Lone Oak Bayou
Robinson Bayou
Smith Pt.
Marsh Pt.
TRINITY RIVER CHANNEL
Clear Lake
44%
25%
31%
HOUSTON SHIP CHANNEL
ABOVE MORGANS POINT EXCLUDING BAYTOWN
39%
61%
CLEAR CREEK AREA
MORGAN POINT TO EAGLE POINT
Red Fish Bar
Eagle Pt.
April Fool Pt.
Dickinson Bay
Hanna Reef
GALVESTON BAY
HOUSTON SHIP CHANNEL
EAST BAY
BOLIVAR PENINSULA
Dollar Pt.
Dollar Bay
10%
90%
TEXAS CITY AREA
INCLUDES DICKINSON BAYOU & GALVESTON
TEXAS CITY DIKE
Port Bolivar
LEGEND
AREA REPRESENTS
200 MGD
PELICAN ISLAND
GALVESTON
WEST BAY
GALVESTON ISLAND
Carancahua Reef
Chocolate Bay
San Luis Pass
GULF OF MEXICO
0 1 2 3 4 5
SCALE IN MILES

▨ PETROLEUM, CHEMICAL, PLASTICS, & RUBBER INDUSTRIES

▩ MUNICIPAL & DOMESTIC

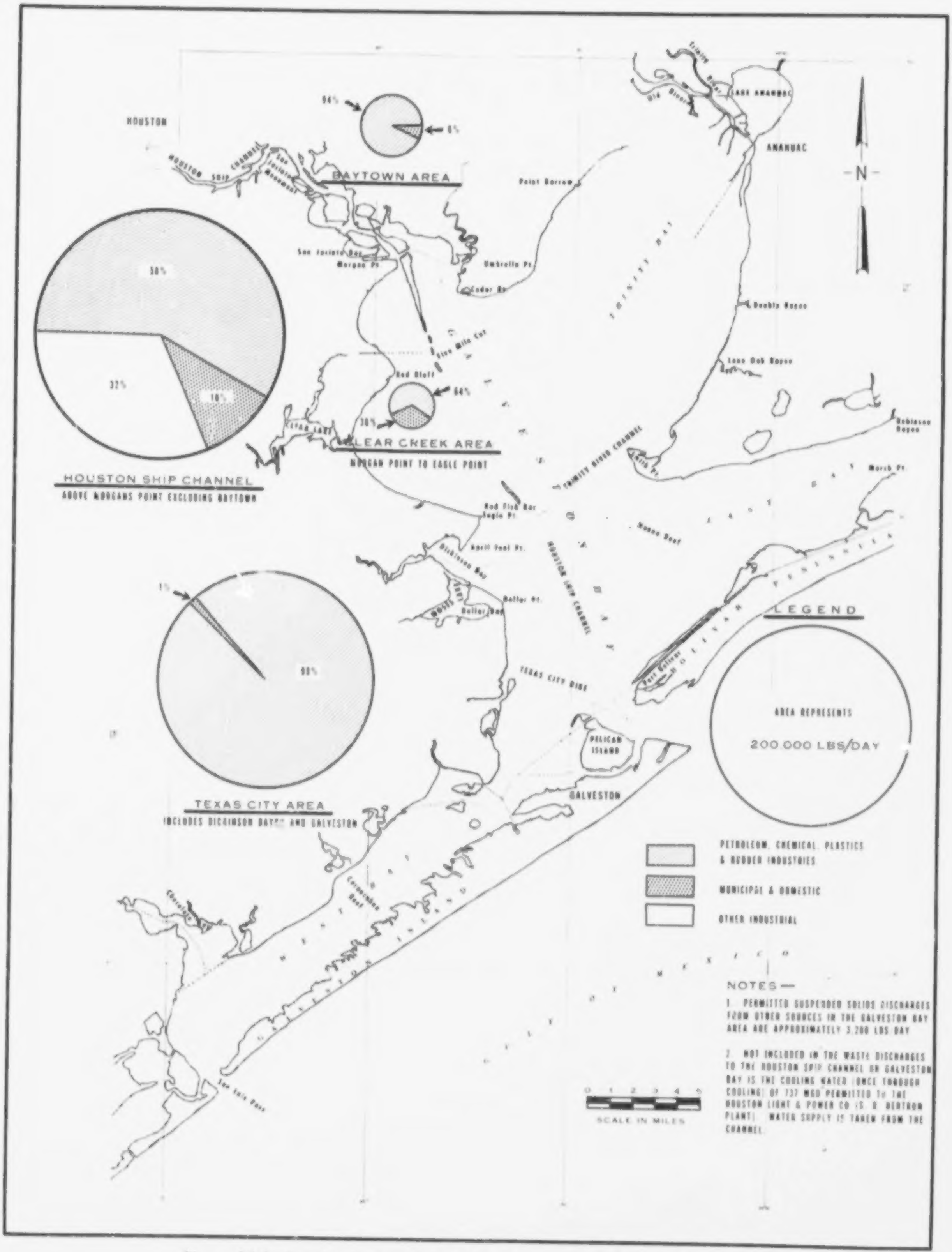
☐ OTHER INDUSTRIAL

NOTES -

1 PERMITTED WASTE WATER DISCHARGES FROM OTHER SOURCES IN THE GALVESTON BAY AREA ARE APPROXIMATELY 17.5 MGD

2 NOT INCLUDED IN THE WASTE DISCHARGES TO THE HOUSTON SHIP CHANNEL OR GALVESTON BAY IS THE COOLING WATER (ONCE THROUGH COOLING) OF 737 MGD PERMITTED TO THE HOUSTON LIGHT & POWER CO. (S. R. BERTRON PLANT); WATER SUPPLY IS TAKEN FROM THE CHANNEL

Figure VI-1 Permitted Wastewater Discharges in the Galveston Bay Area

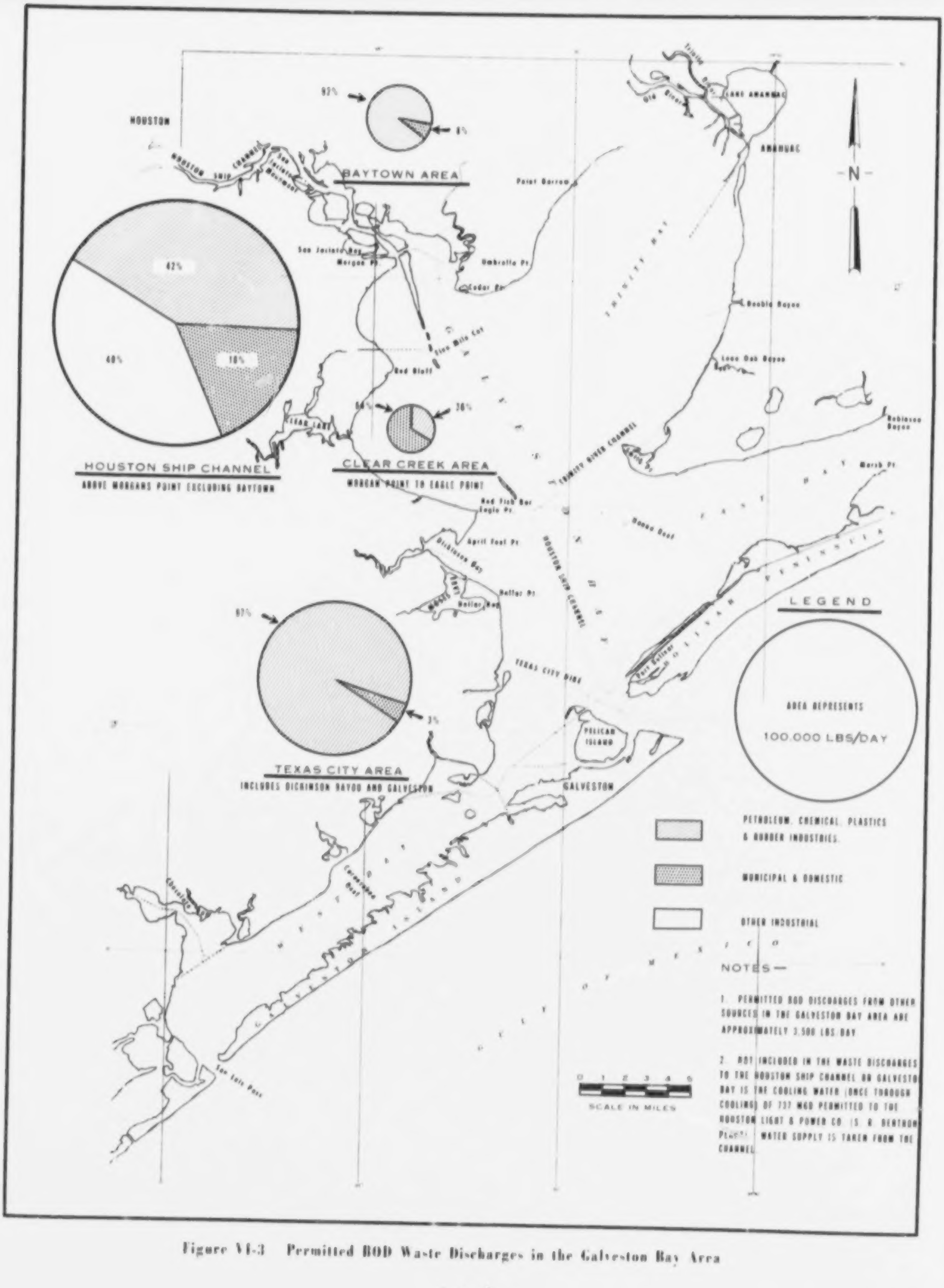

HOUSTON
HOUSTON SHIP CHANNEL
San Jacinto Monument
BAYTOWN AREA
94%
6%
HOUSTON SHIP CHANNEL
ABOVE MORGANS POINT EXCLUDING BAYTOWN
58%
32%
10%
CLEAR CREEK AREA
MORGAN POINT TO EAGLE POINT
64%
36%
TEXAS CITY AREA
INCLUDES DICKINSON BAYOU AND GALVESTON
1%
99%
San Jacinto Bay
Morgan Pt.
Umbrella Pt.
Cedar Bayou
Point Barrow
Five Mile Cut
Red Bluff
Clear Lake
Red Fish Bar
Eagle Pt.
April Fool Pt.
Dickinson Bay
Moses Lake
Dollar Bay
Dollar Pt.
Texas City Dike
Pelican Island
GALVESTON
Trinity River
Old River
LAKE ANAHUAC
ANAHUAC
TRINITY BAY
Double Bayou
Lone Oak Bayou
Robinson Bayou
Smith Pt.
TRINITY RIVER CHANNEL
HOUSTON SHIP CHANNEL
Hanna Reef
EAST BAY
Marsh Pt.
BOLIVAR PENINSULA
Port Bolivar
GALVESTON BAY
WEST BAY
Carancahua Reef
Chocolate Bay
GALVESTON ISLAND
San Luis Pass
GULF OF MEXICO
N
LEGEND
AREA REPRESENTS
200,000 LBS/DAY
PETROLEUM, CHEMICAL, PLASTICS & RUBBER INDUSTRIES
MUNICIPAL & DOMESTIC
OTHER INDUSTRIAL
0 1 2 3 4 5
SCALE IN MILES

NOTES—

1. PERMITTED SUSPENDED SOLIDS DISCHARGES FROM OTHER SOURCES IN THE GALVESTON BAY AREA ARE APPROXIMATELY 3,200 LBS DAY

2. NOT INCLUDED IN THE WASTE DISCHARGES TO THE HOUSTON SHIP CHANNEL OR GALVESTON BAY IS THE COOLING WATER (ONCE THROUGH COOLING) OF 737 MGD PERMITTED TO THE HOUSTON LIGHT & POWER CO (S. R. BERTRON PLANT). WATER SUPPLY IS TAKEN FROM THE CHANNEL.

Figure VI-2 Permitted Suspended Solids Discharges in Galveston Bay Area


HOUSTON
HOUSTON SHIP CHANNEL
92%
8%
BAYTOWN AREA
42%
40%
18%
HOUSTON SHIP CHANNEL
ABOVE MORGANS POINT EXCLUDING BAYTOWN
64%
36%
CLEAR CREEK AREA
MORGAN POINT TO EAGLE POINT
97%
3%
TEXAS CITY AREA
INCLUDES DICKINSON BAYOU AND GALVESTON
Trinity River
Old River
ANAHUAC
Point Barrow
San Jacinto Bay
Morgan Pt
Umbrella Pt
Cedar Pt
TRINITY BAY
Double Bayou
Red Bluff
Five Mile Cut
Clear Lake
Lone Oak Bayou
Robinson Bayou
TRINITY RIVER CHANNEL
Smith Pt
Marsh Pt
Red Fish Bar
Eagle Pt
April Fool Pt
Dickinson Bay
Hanna Reef
EAST BAY
HOUSTON SHIP CHANNEL
GALVESTON BAY
Dollar Pt
BOLIVAR PENINSULA
Port Bolivar
TEXAS CITY DIKE
PELICAN ISLAND
GALVESTON
WEST BAY
GALVESTON ISLAND
San Luis Pass
GULF OF MEXICO
-N-
LEGEND
AREA REPRESENTS
100,000 LBS/DAY
PETROLEUM, CHEMICAL, PLASTICS & RUBBER INDUSTRIES.
MUNICIPAL & DOMESTIC
OTHER INDUSTRIAL
0 1 2 3 4 5
SCALE IN MILES

NOTES—

1. PERMITTED BOD DISCHARGES FROM OTHER SOURCES IN THE GALVESTON BAY AREA ARE APPROXIMATELY 3,500 LBS/DAY

2. NOT INCLUDED IN THE WASTE DISCHARGES TO THE HOUSTON SHIP CHANNEL OR GALVESTON BAY IS THE COOLING WATER (ONCE THROUGH COOLING) OF 737 MGD PERMITTED TO THE HOUSTON LIGHT & POWER CO. (S. R. BERTRON PLANT). WATER SUPPLY IS TAKEN FROM THE CHANNEL.

Figure VI-3 Permitted BOD Waste Discharges in the Galveston Bay Area

64d

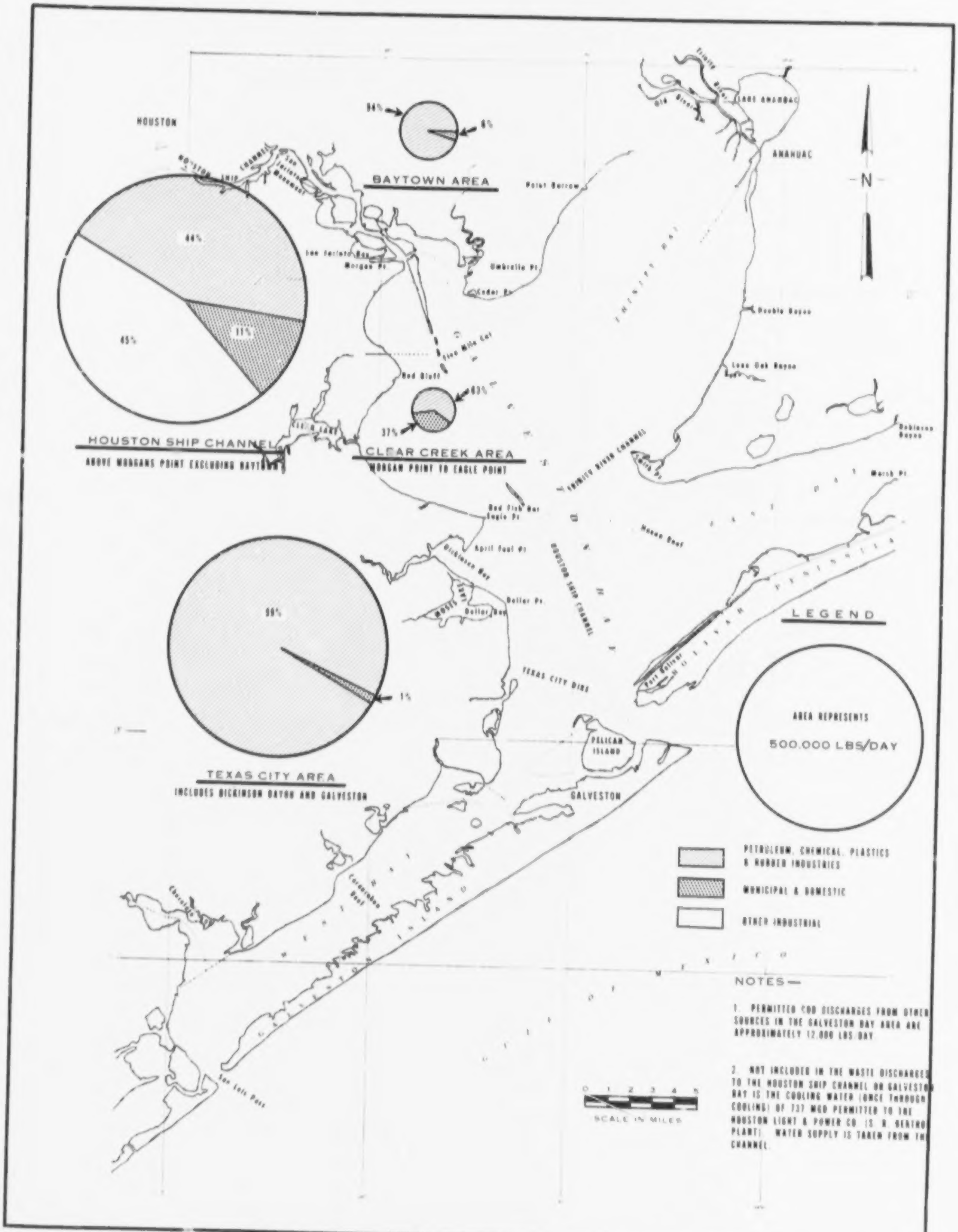

HOUSTON
HOUSTON SHIP CHANNEL
San Jacinto Monument
94%
6%
BAYTOWN AREA
Point Barrow
San Jacinto Bay
Morgan Pt
Umbrella Pt
Cedar Pt
Five Mile Cut
Red Bluff
44%
11%
45%
63%
37%
HOUSTON SHIP CHANNEL
ABOVE MORGANS POINT EXCLUDING BAYTOWN
Clear Lake
CLEAR CREEK AREA
MORGAN POINT TO EAGLE POINT
Trinity River
Old River
LAKE ANAHUAC
ANAHUAC
N
TRINITY BAY
Double Bayou
Lone Oak Bayou
Robinson Bayou
Smith Pt
TRINITY RIVER CHANNEL
Marsh Pt
EAST BAY
Moses Reef
Red Fish Bar
Eagle Pt
April Fool Pt
Dickinson Bay
Dollar Pt
Dollar Bay
GALVESTON BAY
HOUSTON SHIP CHANNEL
TEXAS CITY DIKE
99%
1%
TEXAS CITY AREA
INCLUDES DICKINSON BAYOU AND GALVESTON
PELICAN ISLAND
GALVESTON
Port Bolivar
BOLIVAR PENINSULA
LEGEND
AREA REPRESENTS
500,000 LBS/DAY
PETROLEUM, CHEMICAL, PLASTICS & RUBBER INDUSTRIES
MUNICIPAL & DOMESTIC
OTHER INDUSTRIAL
WEST BAY
Carancahua Reef
Chocolate Bay
GALVESTON ISLAND
GULF OF MEXICO
San Luis Pass
0 1 2 3 4 5
SCALE IN MILES

Figure VI-1 Permitted COD Waste Discharges in the Galveston Bay Area

NOTES—

1. PERMITTED COD DISCHARGES FROM OTHER SOURCES IN THE GALVESTON BAY AREA ARE APPROXIMATELY 12,000 LBS/DAY.

2. NOT INCLUDED IN THE WASTE DISCHARGES TO THE HOUSTON SHIP CHANNEL OR GALVESTON BAY IS THE COOLING WATER (ONCE THROUGH COOLING) OF 737 MGD PERMITTED TO THE HOUSTON LIGHT & POWER CO. (S. R. BERTRON PLANT). WATER SUPPLY IS TAKEN FROM THE CHANNEL.

Effluent data collected by the Texas Water Quality Board February 1969 showed total coliform concentrations at both plants to be 34,800,000/100 ml. Fecal coliform concentrations were 13,000,000/100 ml and 3,300,000/100 ml at the Northside and Sims Bayou plants, respectively.

At least 4 MGD of domestic wastes is being discharged to the Galveston Bay system with no treatment. Harris County Sewer Districts discharge waste from 27 sources, only one of which has a flow of one MGD. The City of Houston has four additional sources not discharging to the Ship Channel, for a total of 41. Galveston has three sources and Baytown has five. More than 110 MGD of raw, inadequately treated, or unchlorinated sewage is discharged to Galveston Bay. The multiplicity of waste treatment plants constructed by each political subdivision is wasteful of resources and does not provide adequate operations to assure the best treatment for domestic sewage. A program of centralization of treatment facilities and abandonment of small plants, with a firm implementation schedule, should be undertaken at the earliest time. Effective year round chlorination should be initiated immediately for all existing domestic effluents.

B. INDUSTRIAL WASTE DISCHARGES

The 136 industrial waste dischargers are permitted a total effluent of about 563 MGD containing 540,000 pounds per day of suspended solids, 230,300 pounds per day of BOD, and 1,538,200 pounds per day of COD. Petroleum and related industries, amounting to 75 sources, account for 81 percent of the suspended solids permitted, 68 percent of the BOD, and 74.5 percent of the COD.

The Houston Ship Channel receives the major portion of industrial waste discharges to the Galveston Bay system. The permitted waste effluent totals are about equally divided between petroleum and related industries with 48 sources and other industries amounting to 53 sources. The Houston Ship Channel may receive 283,500 pounds per day of suspended solids, 149,500 pounds per day of BOD, and 783,900 pounds per day of COD. The major sources of waste discharged to the Ship Channel are the Diamond Shamrock Company at Deer Park with more than 149 MGD, Ethyl Corporation with 26 MGD, Humble Oil and Refining Company with 25 MGD, Armco Steel Corporation with 32.5 MGD, U.S. Plywood-Champion Paper Company with 44 MGD, and Southland Paper Mills with 50 MGD. Of the total 101 industrial sources permitted to discharge wastes to the Houston Ship Channel, these six effluents account for 83 percent of the suspended solids, 78 percent of the BOD, and 79 percent of the COD. Three of these sources, Diamond Shamrock, U.S. Plywood-Champion Paper, and Southland Paper Mills account for 72 percent, 64 percent, and 67 percent of the total amount of suspended solids, BOD, and COD, respectively, discharged daily to the Houston Ship Channel. Diamond Shamrock discharges heavy metals, particularly mercury, without adequate treatment. There is also a need for pH control and solids containment at this plant. Armco Steel Corporation has been discharging phenols and cyanide, an extremely toxic substance. Adequate treatment is not provided at Southland Paper Mills. Excessive color is a constituent of the waste effluent from both U.S. Plywood-Champion Paper and Southland Paper Mills. U.S. Plywood-Champion Paper is now completing secondary treatment facilities. The treatment at Ethyl consists of an oyster shale barrier for pH control and an oxidation pond. Humble Oil at Baytown has aerated lagoons and is said to be in compliance with permit requirements.

Although the Texas permits specify that 180,800 pounds per day of BOD may be discharged from municipal and industrial sources to the Houston Ship Channel, studies conducted in the Channel during 1968 and 1969 indicate that as much as 363,000 pounds per day of five day BOD is the actual loading[1/]. The aggregate total of waste discharges is in substantial noncompliance with the Texas Water Quality Board permits. To meet the requirements of the Texas Water Quality Board, a 50 percent reduction of wastes discharged to the Channel is mandatory in addition to any reductions already accomplished. The conclusion of the study cited indicates that, even if the requirements of the permits are met, the dissolved oxygen criterion of 2 mg/l, established in the Texas Water Quality Requirements for the most polluted section of the Ship Channel, will continue to be violated. Approximately 90 percent additional

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[1/] Kramer, G. R., R. W. Hann, and S. B. Carpenter, "Completely Mixed Model of the Houston Ship Channel", Estuarine Systems Projects, Technical Report No. 11, Environmental Engineering Division, Texas A&M University.

treatment of wastes is needed to maintain a dissolved oxygen level of 2.0 mg/l. These studies were based on BOD loadings and did not account for any long-term or second stage oxygen demands. Under these circumstances, and since it has been demonstrated that BOD does not adequately characterize the oxygen demanding effects of wastes discharged to the Galveston Bay system due to the discharge of toxic or growth inhibiting substances in the waste effluents, the estimate of 90 percent additional treatment is conservative. It is probable that greater than 90 percent additional treatment will be required to meet the applicable receiving water criteria. The Texas discharge permits should be revised such that effluent discharges are consistent with established water quality standards.

The permits allow the discharge of 315,000 pounds per day of suspended solids to the Ship Channel. Materials dredged from the Ship Channel contain substantial quantities of organic sludges, oil, and other pollutants characteristic of wastes discharged to the Channel. About one-third of the BOD loading and one-half of the suspended solids discharged settle out and are incorporated in the bottom sediments[2/]. These waste materials contribute a substantial portion of the sediments which must periodically be removed by dredging. The total project cost for dredging the Houston Ship Channel in 1970 incurred by the U.S. Army Corps of Engineers is

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[2/] Hutton, W. S., R. W. Hann, and R. H. Smith, "A Quantitative and Qualitative Survey of Benthal Deposits Contained in the Houston Ship Channel", Estuarine Systems Projects, Technical Report No. 8, Texas A&M University, May 1970.

$2,807,000. The disposal of this highly organic spoil may cause water quality problems through dispersion of pollutants and through exercise of oxygen demand from the volatile material contained. The additional costs incurred by the Corps of Engineers for dredging of the Houston Ship Channel and the effect on water quality due to disposal of the organic sludge should be evaluated. Recommendations made as a result of this evaluation should include an assessment of damages among the waste dischargers to the Channel and location of suitable spoil disposal areas to minimize or eliminate deleterious effects on water quality.

The other major area of industrial waste discharge to the Galveston Bay system is at Texas City-Dickinson Bayou. There are 17 sources of waste in the area; however, the discharge from the six non-petroleum related sources is negligible. The 11 petroleum related sources are permitted to discharge 234,000 pounds per day of suspended solids, 65,900 pounds per day of BOD, and 686,500 pounds per day of COD. Of this total, the Monsanto Chemical Company at Texas City with 106 MGD contributes the overwhelming majority of the pollution discharged. Suspended solids and COD discharges permitted from Monsanto account for 96 percent and 83 percent, respectively, of the total from the area. Monsanto is not providing adequate waste treatment. An assessment of waste treatment needs for Monsanto includes oil skimming devices, clarification and separation of biologically inert plastics. The major source of BOD waste in the area is the Union Carbide Chemical Company at Texas City with 10.2 MGD. Union Carbide is permitted to discharge 70 percent of the total BOD load in this area. Currently, the waste discharge is in non-compliance with the permit. American Oil Company at Texas City with 13 MGD is also a major waste discharger. The effluent is not in compliance with the permit.

Texas Gulf Sulfur Company at Moss Bluff discharges 4.5 MGD to the Trinity Bay area. The status of treatment is not known. The Monsanto Chemical Company at Chocolate Bayou discharges 2.9 MGD in the West Bay area. The treatment provided is inadequate.

Although the Texas Water Quality Standards state that receiving waters shall be "substantially free" of oil, the permits issued by the Texas Water Quality Board allow more than 55,000 pounds per day of oil and grease to be discharged from 81 sources into Galveston Bay and its tributaries. Seventy-four of these sources are located on the Houston Ship Channel, accounting for 98 percent of the total permitted discharge. The major sources of oil discharge are: Diamond Shamrock Corporation at Deer Park, 12,500 pounds per day; U.S. Plywood-Champion Papers Company, 9,200 pounds per day; Armco Steel Company, 6,800 pounds per day; Atlantic Richfield Company, 8,100 pounds per day; Humble Oil and Refining Company, 4,200 pounds per day; and Southland Paper Mills, 4,170 pounds per day. Shell Chemical Company and Crown Central Petroleum Company may discharge 1,270 and 1,200 pounds per day, respectively. These eight sources account for 86 percent of the permitted discharges.

Excessive concentrations of oil and petrochemical residues have been found in oysters taken from Galveston Bay. The Texas permits should be amended to allow no discharge of oil and grease from any waste source. The permitted discharge of oil from these waste sources constitutes violation of Section 11(b) of the Federal Water Pollution Control Act, as amended.

The petrochemical and related industries constitute the major pollution dischargers to Galveston Bay and its tributaries. Discharge permits specify suspended solids, BOD and COD. These parameters are not adequate to measure the water quality impact of these industrial wastes because of the variety and complexity of compounds in the effluents. Table VI-3 lists typical pollutants which may result from various petrochemical processes[3/]. Many of these waste compounds have toxic, growth inhibiting or carcinogenic effects. Several of these effects have been noted on marine life in Galveston Bay and the Houston Ship Channel and aromatic hydrocarbons, not of natural origin, were recovered from oysters. (See Chapter V). However, no data are available on the specific types of pollutants being discharged by the numerous petrochemical industries.

Other manufacturing processes in the Galveston Bay area produce wastes containing toxic metals which have been observed in the receiving waters. Table VI-4 lists those municipal and industrial sources discharging large quantities of one or more heavy metals.

[3/] Gloyna, E. F., and D. L. Ford, The Characteristics and Pollutional Problems Associated with Petrochemical Wastes, Summary Report, Engineering Science Inc./Texas, Austin, Texas, February 1970.

TABLE VI-3

POLLUTANTS ASSOCIATED WITH VARIOUS PETROCHEMICAL PROCESSES

Process	Source	Pollutants
Alkylation: Ethylbenzene		Tar, Hydrochloric Acid, Caustic Soda, Fuel Oil
Ammonia Production	Demineralization	Acid, Bases
	Regeneration, Process Condensates	Ammonia
	Furnace Effluents	Carbon Dioxide, Carbon Monoxide
Aromatics Recovery	Extract Water	Aromatic Hydrocarbons
	Solvent Purification	Solvents - Sulfur Dioxide, Diethylene Glycol
Catalytic Cracking	Catalyst Regeneration	Spent Catalyst, Catalyst Fines (Silica, Alumina Hydrocarbons, Carbon Monoxide, Nitrogen Oxides)
	Reactor Effluents and Condensates	Acids, Phenolic Compounds, Hydrogen Sulfide Soluble Hydrocarbons, Sulfur Oxides, Cyanides
Catalytic Reforming	Condensates	Catalyst (particularly Pt, Mo), Aromatic Hydrocarbons, Hydrogen Sulfide, Ammonia
Crude Processing	Crude Washing	Inorganic Salts, Oils, Water Soluble Hydrocarbons
	Primary Distillation	Hydrocarbons, Tars, Ammonia, Acids, Hydrogen Sulfide
Cyanide Production	Water Slops	Hydrogen Cyanide, Unreacted Soluble Hydrocarbons
Dehydrogenation		
Butadiene Prod. from n-Butane and Butylene	Quench Waters	Residue Gas, Tars, Oils, Soluble Hydrocarbons
Ketone Production	Distillation Slops	Hydrocarbon Polymers, Chlorinated Hydrocarbons, Glycerol, Sodium Chloride
Styrene from Ethylbenzene	Catalyst	Spent Catalyst (Fe, Mg, K, Cu, Cr, Zn)
	Condensates from Spray Tower	Aromatic Hydrocarbons, including Styrene, Ethylbenzene, and Toluene, Tars
Desulfurization		Hydrogen Sulfide, Mercaptans
Extraction and Purification		
Isobutylene	Acid and Caustic Wastes	Sulfuric Acid, C_4 Hydrocarbon, Caustic Soda
Butylene	Solvent and Caustic Wash	Acetone, Oils, C_4 Hydrocarbon, Caustic Soda, Sulfuric Acid
Styrene	Still Bottoms	Heavy Tars
Butadiene Absorption	Solvent	Cuprous Ammonium Acetate, C_4 Hydrocarbons, Oils
Extractive Distillation	Solvent	Furfural, C_4 Hydrocarbons
Halogenation (Principally Chlorination)		
Addition to Olefins	Separator	Spent Caustic
Substitution	HCl Absorber, Scrubber	Chlorine, Hydrogen Chloride, Spent Caustic, Hydrocarbon Isomers and Chlorinated Products, Oils
	Dehydrohalogenation	Dilute Salt Solution
Hypochlorination	Hydrolysis	Calcium Chloride, Soluble Organics, Tars

TABLE VI-3 (Continued)

POLLUTANTS ASSOCIATED WITH VARIOUS PETROCHEMICAL PROCESSES

Process	Source	Pollutants
Hydrochlorination	Surge Tank	Tars, Spent Catalyst, Alkyl Halides
Hydrocarboxylation (OXO Process)	Still Slops	Soluble Hydrocarbons, Aldehydes
Hydrocyanation (for Acrylonitrile, Adipic Acid, etc.)	Process Effluents	Cyanides, Organic and Inorganic
Isomerization in General	Process Wastes	Hydrocarbons; Aliphatic, Aromatic, and Derivative Tars
Nitration		
Paraffins		By-Product Aldehydes, Ketones, Acids, Alcohols, Olefins, Carbon Dioxide
Aromatics		Sulfuric Acid, Nitric Acid, Aromatics
Oxidation		
Ethylene Oxide and Glycol Manufacture	Process Slops	Calcium Chloride, Spent Lime, Hydrocarbon Polymers, Ethylene Oxide, Glycols, Dichloride
Aldehydes, Alcohols, and Acids from Hydrocarbons	Process Slops	Acetone, Formaldehyde, Acetaldehyde, Methanol, Higher Alcohols, Organic Acids
Acids and Anhydrides from Aromatic Oxidation	Condensates Still Slops	Anhydrides, Aromatics, Acids Pitch
Phenol and Acetone from Aromatic Oxidation	Decanter	Formic Acid, Hydrocarbons
Carbon Black Manufacture	Cooling, Quenching	Carbon Black, Particulates, Dissolved Solids
Polymerization, Alkylation	Catalysts	Spent Acid Catalysts (phosphoric Acid), Aluminum Chloride
Polymerization (Polyethylene)	Catalysts	Chromium, Nickel, Cobalt, Molybdenum
Butyl Rubber	Process Wastes	Scrap Butyl, Oil, Light Hydrocarbons
Copolymer Rubber	Process Wastes	Butadiene, Styrene Serum, Softener Sludge
Nylon 66	Process Wastes	Cyclohexane Oxidation Products, Succinic Acid, Adipic Acid, Glutaric Acid, Hexamethylene, Diamine, Adiponitrile, Acetone, Methyl Ethyl Ketone
Sulfation of Olefins		Alcohols, Polymerized Hydrocarbons, Sodium Sulfate, Ethers
Sulfonation of Aromatics	Caustic Wash	Spent Caustic
Thermal Cracking for Olefin Production (including Fractionation and Purification)	Furnace Effluent and Caustic Treating	Acids, Hydrogen Sulfide, Mercaptans, Soluble Hydrocarbons, Polymerization Products, Spent Caustic, Phenolic Compounds, Residue Gases, Tars and Heavy Oils
Utilities	Boiler Blow-down	Phosphates, Lignins, Heat, Total Dissolved Solids, Tannins
	Cooling System Blow-down	Chromates, Phosphates, Algicides, Heat
	Water Treatment	Calcium and Magnesium Chlorides, Sulfates, Carbonates

TABLE VI-4

DISCHARGES OF HEAVY METALS TO THE HOUSTON SHIP CHANNEL[1/]

Industry or Municipality	Outfall Code Number	Flow MGD	Heavy Metals - lb/day				
			Zinc	Lead	Chromium	Cadmium	Copper
Olin Mathieson (Pasadena)	27-1	8.64	930	43	22	22	303
	27-3	1.44	57	6	-	-	-
Diamond Shamrock	47-1	5.00	320	25	-	-	-
	47-2	90.00	975	1,420	150	1,050	1,875
	47-5	2.88	72	29	-	-	-
Armco Steel Corp.* (Sheffield)	28-56	3.50	146	-	-	-	-
Dupont (LaPorte)	60	2.00	168	-	8	-	-
Houston Lighting & Power Co. (Bertron)	58-0	0.51	-	16	-	-	-
Ideal Cement	8-1	1.44	210	13	5	6	-
Goodyear Tire (Houston)	10-2	0.36	-	-	6	-	-
Lubrizol Corp.	45-1	0.75	100	-	-	-	-
Humble Oil (Houston)	61-1	9.00	540	-	30	15	-
Northside Sewage Treatment Plant (Houston)	65-1	28.00	1,030	-	47	-	-
	65-2	20.00	300	-	-	-	-
Petro-Tex Chemical	9-2	3.10	196	-	10	-	-
Rohm & Haas (Deer Park)	51-2 (API)	0.50	21	-	16	-	-
	51-1	1.00	16	-	9	-	-
	51-2	1.00	40	-	8	-	-
Shell Chemical Co. (Deer Park)	44-1	8.20	550	-	-	-	-
Southland Paper (Pasadena)	41	13.60	215	68	-	-	-
Stauffer Chemical (Manchester)	3	0.65	65	2	2	2	102
Upjohn (Carwin)	55	0.61	117	8	5	3	-
Tenneco Chemical (Pasadena)	42-1	2.40	38	-	18	-	20
U.S. Plywood (Pasadena)	21	38.00	1,780	-	-	-	32
Totals	-	242.58	7,886	1,630	336	1,098	2,332

* Twenty-four-hour composite samples collected by the FWQA, South Central Region, showed that this industry was discharging approximately 1,000 lbs. of cyanide and 400 lbs. per day of phenols to the Houston Ship Channel. The Justice Department recently filed suit against this industry under the 1899 Refuse Act.

[1/] Based on effluent data (grab samples only) collected by the Texas Water Quality Board in February 1969. Additional field data are necessary to determine if the samples collected are representative.

Of the 277 municipal and industrial waste sources having discharge permits in the Galveston Bay area, the waste treatment needs and status of 189 are not listed. Where needs are indicated, 40 sources provide inadequate or no treatment and no abatement, beyond engineering studies in a few instances, is in progress. Seventeen sources have treatment facilities in progress; 22 are said to be in compliance with permit requirements. Nine sources either provide adequate treatment or have no needs. These evaluations are based on the inadequate characterization of wastes according to the parameters listed in the Texas permits. An effective waste abatement program is not now being conducted in the Galveston Bay area. A waste source inventory, including characterization of specific compounds discharged, as well as evaluation of present treatment practices and additional needs for each effluent is urgently required. The Texas permits should be revised to reflect the required removal of waste substances causing deleterious effects or hazardous conditions in the receiving waters. A firm compliance schedule for each effluent should be included in the discharge permit.

A summary of municipal and industrial waste discharges by area is listed in Table VI-5.

C. OTHER SOURCES

Many of the small coastal streams entering Galveston Bay flow through heavily industrialized and urban areas. These streams carry surface runoff from such areas following periods of precipitation. Biochemical oxygen demand of urban runoff from the Houston area is

TABLE VI-5
SUMMARY OF PERMITTED WASTE DISCHARGES - GALVESTON BAY AREA

Area	MUNICIPAL AND DOMESTIC					PETROLEUM, CHEMICAL, PLASTIC, AND RUBBER INDUSTRIES					OTHER INDUSTRIAL				
	Number of Sources	Flow MGD	S.S. 1,000 #/day	BOD 1,000 #/day	COD* 1,000 #/day	Number of Sources	Flow MGD	S.S. 1,000 #/day	BOD 1,000 #/day	COD 1,000 #/day	Number of Sources	Flow MGD	S.S. 1,000 #/day	BOD 1,000 #/day	COD 1,000 #/day
Houston Ship Channel and Tributaries excluding Baytown	90	172.2	31.5	31.3	95.2	48	245.2	183.0	76.3	391.1	53	139.6	100.2	73.2	392.8
Baytown Area	7	5.3	1.0	1.0	2.9	5	27.6	15.7	11.2	45.9	-	-	-	-	-
Clear Creek Area (Morgan Point to Eagle Point)	26	15.9	3.0	3.0	8.9	8	10.0	5.3	1.7	15.5	1	-- N E G L I G I B L E --			
Texas City, Galveston, and Dickinson Bayou Areas	6	13.5	2.2	2.2	6.7	11	132.3	234.0	65.9	686.5	6	-- N E G L I G I B L E --			
Trinity Bay and Tributaries	4	2.0	0.4	0.5	1.4	1	4.5	0.8	0.8	2.3	-	-	-	-	-
West Bay and Tributaries	8	6.5	1.3	1.3	3.8	2	3.2	0.8	0.8	2.4	1	1.0	0.6	0.4	1.7
TOTALS	141	215.4	39.4	39.3	118.9	75	422.8	439.6	156.7	1143.7	61	140.6	100.8	73.6	394.5

TOTAL OF ALL SOURCES[1/] Number of Sources = 277; Flow-MGD = 778.8; S.S. (1,000 #/day)= 583.2; BOD (1,000 #/day)= 269.6; COD (1,000 #/day)= 1,657.1

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* COD Values for all but three municipal and domestic sources - all estimated.

[1/] Not included in the total waste discharges to the Houston Ship Channel and the Bay is the cooling water discharge (once through flow) of 737.2 MGD permitted to Houston Light and Power Company (S. R. Bertron Plant). Water supply is taken from the Channel.

about 20 mg/l which is comparable to weak municipal wastes. For the 1963-68 period, BOD discharged to the upper 25 miles of the Houston Ship Channel by urban runoff was estimated to average about 92,000 pounds per year. The suspended solids load from urban runoff averaged 550,000 pounds per year from 1963-68[4/].

Rural runoff from areas in the Trinity and San Jacinto River basins may contribute silt and nutrients to the estuary. Construction and operation of Livingston and Wallisville Reservoirs on the Trinity River will substantially reduce the silt load to Galveston Bay.

4/ Hutton, W. S., R. W. Hann, and R. H. Smith, "A Quantitative and Qualitative Survey of Benthal Deposits Contained in the Houston Ship Channel", Estuarine Systems Projects, Technical Report No. 8, Texas A&M University, May 1970.

VII. ECONOMIC IMPACT OF POLLUTION

Harvesting of shellfish, primarily oysters, has a significant economic value to the Galveston Bay estuary. Bacterial pollution has closed a substantial portion of the estuary to the harvesting of shellfish. Toxic materials and sediments discharged to the estuarial waters have reduced the areas which will support commercially harvestable populations of shellfish[1]. The depuration of oysters harvested from certain areas is required before the oysters may be marketed, resulting in increased costs to oystermen. The direct economic loss incurred by the shellfish industry as a result of impaired shellfish production produces an associated economic impact on the regional economy.

A. SHELLFISH AREAS CLOSED BY POLLUTION

For at least the last twenty years, a substantial portion of the estuary has been closed to the taking of shellfish for human consumption. Bacteriological criteria and proximity to sources of pollution were the determining factors in defining closed areas. Between 1951 and 1970, the area closed to shellfish harvesting ranged from 205,000 acres to 155,000 acres, or about two-thirds to one-half of the estuarine area. The classifications of various areas of

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1/ Hutton, W. S., R. W. Hann, and R. H. Smith, "A Quantitative and Qualitative Survey of Benthal Deposits Contained in the Houston Ship Channel", Estuarine Systems Projects, Technical Report No. 6, Texas A&M University, May 1970.

the estuary relative to shellfish harvesting as established for the 1970-71 shellfish season are shown in Figure VII-1.

Between 1955 and the present, three significant changes were made in the sizes and locations of the closed and open areas. The total area open in 1955 approximated the open area for 1966 although boundaries differed slightly. Between 1955 and 1958, the open area remained about the same. In 1958, open areas in upper Galveston Bay were reduced in size and a conditionally approved area was established. The conditionally approved area, which had essentially the same boundaries as shown in Figure VII-1, was subject to temporary closure following periods of high surface runoff. The open areas retained the same boundaries until 1966 when an additional area in lower Trinity Bay was opened to shellfish harvesting. The Trinity Bay area was again enlarged in 1969, establishing the open area boundaries shown in Figure VII-1.

The major changes in open and closed areas over the past 15 years have been in upper Galveston Bay and Lower Trinity Bay. Only limited areas of commercially important oyster producing reefs were changed in classification. The actual oyster producing area approved for harvesting has remained relatively the same for the past ten years. Although the water area open for shellfish taking has been substantially increased over the past twenty years, the actual area of producing reefs has not been proportionately increased and has probably decreased as a result of destruction of reefs by siltation and shell dredging.

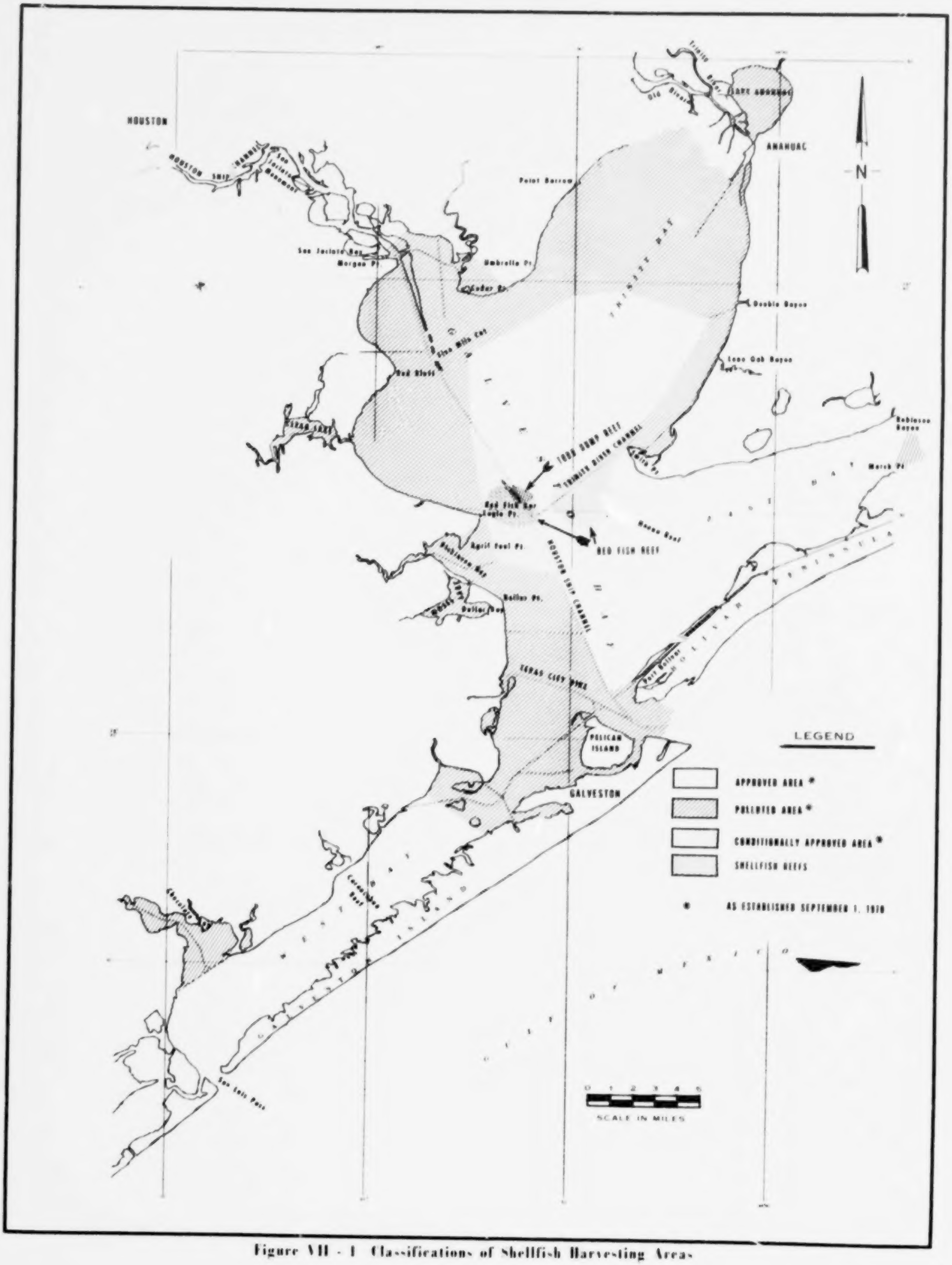
HOUSTON
HOUSTON SHIP CHANNEL
San Jacinto Monument
ANAHUAC
LAKE ANAHUAC
Trinity River
Old River
N
Point Barrow
TRINITY BAY
San Jacinto Bay
Morgan Pt.
Umbrella Pt.
Cedar Pt.
Five Mile Cut
Double Bayou
Red Bluff
Lone Oak Bayou
CLEAR LAKE
TODD DUMP REEF
TRINITY RIVER CHANNEL
Smith Pt.
Robinson Bayou
Marsh Pt.
EAST BAY
Red Fish Bar
Eagle Pt.
Hanna Reef
RED FISH REEF
April Fool Pt.
HOUSTON SHIP CHANNEL
Dickinson Bay
Moses Lake
Bolivar Pt.
Dollar Bay
GALVESTON BAY
BOLIVAR PENINSULA
Port Bolivar
TEXAS CITY DIKE
PELICAN ISLAND
GALVESTON
WEST BAY
Carancahua Reef
GALVESTON ISLAND
Chocolate Bay
San Luis Pass
GULF OF MEXICO
LEGEND
APPROVED AREA *
POLLUTED AREA *
CONDITIONALLY APPROVED AREA *
SHELLFISH REEFS
* AS ESTABLISHED SEPTEMBER 1, 1970
0 1 2 3 4 5
SCALE IN MILES

Figure VII - 1 Classifications of Shellfish Harvesting Areas

80b

At present, almost 90 percent of the oyster harvest is taken from Red Fish Reef and the smaller Todd Dump Reef. These reefs are located between Smith Point and Eagle Point in Galveston Bay. Todd Dump Reef and the portion of Red Fish Reef west of the Houston Ship Channel are located in the conditionally approved area. Temporary closures of this area during high streamflow periods can restrict harvesting from a significant portion of the most productive oyster reefs. The frequency and lengths of temporary closures of this area have not been documented.

It is estimated that productive reefs in open shellfishing areas now have a total area of about 9,100 acres. Estimates of shellfish areas open to harvesting in the past were utilized to determine the approximate annual yield of oyster meat from one acre of productive reef. Except for 1965, this yield has remained relatively stable for the 1963-69 period. The average yield for this period was considered representative of the level of production per acre that could be sustained under normal conditions in the Galveston Bay estuary.

B. PRODUCTIVE SHELLFISH BEDS IN CLOSED AREAS

The following statement by Congressman Bob Eckhardt of Texas was presented at a public hearing for the National Estuarine Pollution Study[2/].

[2/] Eckhardt, Bob, U.S. Representative, 8th District Texas, Statement presented by Mr. Keith Ozmore, staff assistant, to National Estuarine Pollution Study Hearing, Galveston, Texas, October 8, 1968.

> "I am informed by the Texas Parks and Wildlife Department that the 42 percent of the estuary which is off-limits for oyster production contains some 1,500 acres of producing oyster reefs, or roughly 15.7 percent of the oyster reefs in the entire estuary. This means that each year we are losing 692,429 pounds of oyster meats, worth some $311,593 because they cannot be marketed. And this does not reflect the total loss. By the time you figure that landed value, this means that we are losing $3,115,930 in the oyster fishery because of pollution."

Another estimate prepared by the Texas Parks and Wildlife Department in 1970 indicated that there are currently 1,000 acres of oyster beds located in polluted areas of which about 500 acres would support commercial harvesting[3/]. Closed productive areas are primarily located in Dickinson Bay and West Bay.

A number of smaller reefs closed to harvesting are located in areas with suitable salinity for oyster production. Some of these reefs support populations of small oysters which do not reach marketable size. It is believed that these reefs could support marketable oysters if suitable water quality enhancement were achieved.

A number of shellfish beds located in closed areas are accessible by foot during low tide, or by small boat. Local health authorities have encountered problems in preventing sport shellfishing in these areas. Consumption of shellfish from these areas poses a health hazard, as the shellfish may be contaminated by bacteria and toxic materials.

[3/] Singleton, J. R., Texas Parks and Wildlife Department, Letter regarding oyster harvesting areas in Galveston Bay within polluted waters; also recent dockside value of oyster harvests in Galveston Bay, November 1970.

C. ECONOMIC DAMAGES

The average yield of producing shellfish beds in open areas provides a reasonable estimate for the average harvest which could be obtained from beds located in closed areas if shellfishing restrictions caused by pollution were removed. The average yield for the 1963-69 period was 392 pounds of oyster meat per acre.

Estimates of producing oyster reefs in the areas closed due to pollution range from 1,500 acres[2/] to 500 acres[3/]. If 1,500 acres could be made commercially available due to abatement of pollution, an additional 588,000 pounds of oyster meat would be harvested. At 1969 prices of $0.44 per pound, this harvest has a dockside value of $258,000. If only 500 acres are commercially available, the dockside value of 196,000 pounds would be $86,000. A recent survey of the Florida shellfish industry states that the final retail value of shellfish products is roughly four times the dockside value[4/]. The economic damage to shellfish harvesters caused by closure of producing shellfish areas due to pollution ranges between $344,000 and $1,030,000 annually.

Approximately 16,000 barrels of oysters were harvested using depuration techniques in the 1968-69 season. The extra handling

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[2/] Eckhardt, Bob, U.S. Representative, 8th District Texas, Statement presented by Mr. Keith Ozmore, staff assistant, to National Estuarine Pollution Study Hearing, Galveston, Texas, October 8, 1968.

[3/] Singleton, J. R., Texas Parks and Wildlife Department, Letter regarding oyster harvesting areas in Galveston Bay within polluted waters; also recent dockside value of oyster harvests in Galveston Bay, November 1970.

[4/] Colbert, J. R., and D. M. Windham, The Oyster Based Economy of Franklin County, Florida, U.S. Public Health Service, DHEW.

in transplanting oysters from polluted areas to approved areas in the depuration process increases the costs of marketing oysters and results in an additional economic impact. It is estimated that the costs associated with depuration in Galveston Bay total $15,000 annually. The total actual damages caused by the inability to market shellfish due to pollution in Galveston Bay are between $359,000 and $1,045,000 annually.

If examination of water quality for approval of areas for shellfish harvesting were regularly conducted under the most unfavorable hydrographic and pollution conditions as required by applicable standards, it is probable that the most productive reefs in Galveston Bay now approved for harvesting, would have to be closed due to excessive bacteriological pollution. These conditions occurred about 40 percent of the time during the 1969 season. Furthermore, concentrations of hydrocarbon residues, exceeding those which resulted in closure of shellfishing areas in West Falmouth Harbor, Massachusetts, have been recovered from Galveston Bay oysters taken from approved areas. Heavy metals concentrations in Galveston Bay waters greatly exceed natural background concentrations. Galveston Bay should be closed to all shellfish harvesting immediately until the health hazard associated with waste discharges is clearly ascertained and eliminated. Consideration should also be given to prohibiting all commercial fishing in Galveston Bay until it has been ascertained that the marine species taken from the Bay are suitable for human consumption. The value of the commercial fishery in Galveston Bay during 1964 was $2,797,400[5/]. Prohibition of commercial fishing represents a substantial economic damage. Assuming a 5 percent rate of return on this renewable resource, commercial fishing represents to the Galveston Bay area a $56,000,000 capital investment, based on 1964 figures, which has been endangered due to pollution from municipal and industrial wastes.

[5/] Eckhardt, Bob, U.S. Representative, 8th District Texas, Statement presented by Mr. Keith Ozmore, staff assistant, to National Estuarine Pollution Study Hearing, Galveston, Texas, October 8, 1968.

VIII. WATER QUALITY IMPACT OF FUTURE DEVELOPMENTS

A. HOUSTON WATER SUPPLY DIVERSION

Development of the Trinity River as an additional water supply for the Houston metropolitan area is nearing the final stages. Wallisville and Livingston Reservoirs on the Trinity River and a pipeline from Wallisville Reservoir to the Houston area are the major features of the Trinity River supply system.

Livingston Reservoir was recently constructed by the Trinity River Authority to provide storage for regulation of flow in the lower river and for increasing the firm yield of the watershed for water supply purposes.

Construction of Wallisville Reservoir was recently initiated by the Corps of Engineers. This reservoir, located about four miles upstream from the mouth of the river and downstream from Livingston Reservoir, will provide a barrier against upstream intrusion of saline water from Trinity Bay during high tide and low flow conditions and will serve as an intake point for the water supply pipeline to Houston. Since the reservoir will have only a small amount of active storage, little regulation of stream flow will be produced other than that achieved by diversions to Houston. Construction of Wallisville Reservoir will inundate part of the productive shrimp nursery areas in Trinity Bay.

Wallisville Reservoir alone will produce only a small effect on water quality in the estuary. The complete Trinity River water supply system will, however, substantially alter circulation and water quality conditions. The most significant effect of the water supply system will be to reduce the freshwater inflow to Trinity Bay. It is estimated that the average freshwater discharge from the Trinity River into Trinity Bay will be decreased by about 13 percent by 1980. This reduction would result from the combination of an average diversions of about 540 cubic feet per second (cfs) through the pipeline to Houston and the depletion of streamflow in the upper watershed due to the expanded needs of the Dallas-Fort Worth area and increased usage for irrigation.

At any point in Trinity Bay, salinity concentrations are primarily a function of the Trinity River discharge. During the spring high flow season, salinity levels throughout the Bay are at their lowest and increase with distance from the mouth of the Trinity River. Salinity levels are the highest during the late summer low flow period. A reduction in average freshwater inflow would thus be expected to produce an increase in average salinity levels. The Corps of Engineers has conducted an evaluation of salinity concentrations and circulation patterns in the entire Galveston Bay estuary system using a physical hydraulic model[1]. Existing (1965) and future (1980) conditions of water use were simulated. The results of the model tests indicated that 1980 average salinity levels would increase slightly (0-10 percent) over 1965 levels at most locations in Trinity Bay with increases as high as 50 percent produced at a few locations for part of the year.

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[1] Bobb, W. H., and R. A. Boland, Jr., Galveston Bay Hurricane Surge Study, Technical Report H-69-12, July 1970, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

The suitability of an estuarine area for a shrimp nursery is highly dependent upon salinity conditions. Abnormal salinity fluctuations can be expected to affect development of juvenile shrimp. Increases in average salinity concentrations will alter the area having salinity levels suitable for a nursery. The average annual value of shrimp harvested from the estuary is nearly $1 million. This harvest represents only a fraction of the adult shrimp produced by the Trinity Bay nursery, as many shrimp caught in other areas were hatched in Trinity Bay. Any reduction in the shrimp production of this nursery would thus have a substantial economic impact.

Water use for municipal and industrial purposes in the Houston metropolitan area is projected to substantially increase in the future. Most of this increased water use will be returned to the estuary, primarily the Houston Ship Channel, as municipal and industrial waste discharges. Additional waste discharges to the Ship Channel will require that higher levels of treatment be provided for all waste sources to maintain acceptable water quality.

Perhaps the most significant result of increased waste discharges would be the augmentation of freshwater inflow to the Ship Channel. It is estimated that this flow augmentation will be almost 200 percent of present low flows under 1980 conditions of water use.

The net effect of the circulation pattern in the Houston Ship Channel is to transport pollutants from the Channel into the Bay via the surface freshwater outflow. Flow augmentation will result in more rapid transport of pollutants to the Bay; the frequency of flushing of the Channel would also increase. If water quality in the Ship Channel is not improved, flow augmentation could result in greater degradation of water quality in the Bay.

B. CEDAR BAYOU POWER PLANT

A large-scale fossil fueled electric generating plant known as the Cedar Bayou Power Plant is being constructed by the Houston Lighting and Power Company at a location on Cedar Bayou near the north shore of Trinity Bay. The plant is scheduled to be built in six stages. Each of the first four stages will consist of one 750-megawatt power unit. The last two stages will add one 1,000-megawatt unit each, bringing the ultimate generating capacity of the plant to 5,000 megawatts. The first unit is scheduled to be on line by mid-1971, with the second unit available about a year later. Completion of all six stages will be in the mid-1980's.

A once-through cooling water system will be utilized by the plant. Water will be drawn into the plant through an intake channel dredged down Cedar Bayou through Tabbs Bay to upper Galveston Bay as shown in Figure VIII-1. As the intake channel through Tabbs Bay is only two to three times the depth of the Bay, some of the cooling

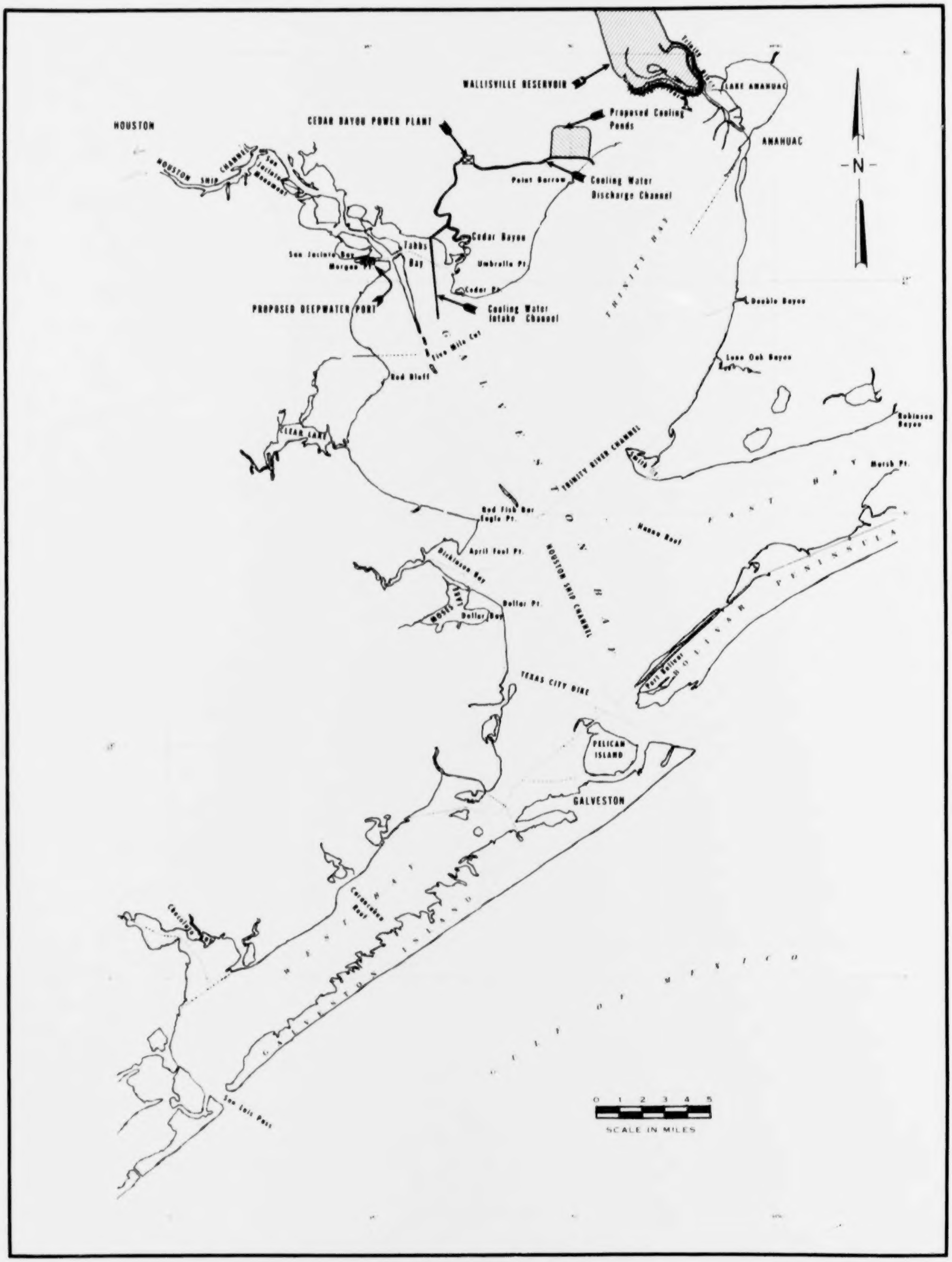
WALLISVILLE RESERVOIR
LAKE ANAHUAC
ANAHUAC
Proposed Cooling Ponds
CEDAR BAYOU POWER PLANT
HOUSTON
HOUSTON SHIP CHANNEL
Point Barrow
Cooling Water Discharge Channel
Cedar Bayou
Tabbs Bay
San Jacinto Bay
Morgan
Umbrella Pt.
Cedar Pt.
PROPOSED DEEPWATER PORT
Cooling Water Intake Channel
TRINITY BAY
Double Bayou
Five Mile Cut
Red Bluff
Lone Oak Bayou
CLEAR LAKE
Robinson Bayou
TRINITY RIVER CHANNEL
GALVESTON BAY
Marsh Pt.
EAST BAY
Red Fish Bar
Eagle Pt.
April Fool Pt.
Dickinson Bay
HOUSTON SHIP CHANNEL
Dollar Pt.
Dollar Bay
BOLIVAR PENINSULA
Port Bolivar
TEXAS CITY DIKE
PELICAN ISLAND
GALVESTON
WEST BAY
GALVESTON ISLAND
GULF OF MEXICO
San Luis Pass
N
0 1 2 3 4 5
SCALE IN MILES

Figure VIII - 1 Future Development

water will be drawn directly from Tabbs Bay. Both Tabbs Bay and upper Galveston Bay receive polluted outflow from the Houston Ship Channel. The point of entrance of the intake channel into Tabbs Bay is about 2 miles from the Houston Ship Channel near Morgan Point.

After passing through the plant's condensers, the heated cooling water will be discharged into a six mile long channel which will convey the flow to upper Trinity Bay near the mouth of the Trinity River. For the operation of the first two stages of the plant, the cooling water will be discharged directly to the Bay. As later stages are constructed a 2,600-acre baffled cooling pond will be added to the discharge channel to provide evaporative cooling before discharge to the Bay.

Operation of the first two power units with a total generating capacity of 1,500 megawatts will require about 1,500 cfs of cooling water. Cooling water requirements are expected to increase to 3,500 cfs in 1980 and 5,000 cfs upon completion of all six stages. By way of comparison, the average discharge of the Trinity River, the major source of freshwater inflow to Trinity Bay, is 7,900 cfs. In 1965, the minimum average weekly flow into the entire Galveston Bay estuary was less than 1,000 cfs.

Operation of the Cedar Bayou Power Plant will impact water quality of the estuary in three major ways. (1) The temperature of the cooling water will be raised by about $20^{\circ}F$ as it passes through the plant's condensers, resulting in the discharge of a large heat load to Trinity Bay. (2) The quality of the water drawn into the system from Tabbs

Bay will be poorer than the present quality of upper Trinity Bay. The cooling water discharge will thus transport pollutants to Trinity Bay. (3) The discharge of large volumes of saline water from Tabbs Bay to the less saline waters of Trinity Bay will increase average salinity concentrations in Trinity Bay.

The Texas Water Quality Board has granted a permit covering the discharge of 1,500 cfs of cooling water from the first two units and has recently granted permits to cover the ultimate 5,000 cfs discharge, over the objections of the Environmental Protection Agency. The present permit allows a maximum temperature of 115°F and a daily average temperature of 110°F at the point of discharge of cooling water to the six mile canal. Some cooling will be achieved in the canal but the discharge to Trinity Bay will still be substantially warmer than existing maximum temperatures, which are in the low 90's.

Under full-scale operation, the cooling ponds will be utilized to remove about one-half of the heat load contained in the cooling water and reduce discharge temperatures. The residual heat load discharged to the Bay will still be sufficient to significantly increase the surface temperature of several square miles of the Bay. The National Technical Advisory Committee on Water Quality Criteria has recommended that the monthly mean of the maximum daily water temperatures should not be increased by more than 1.5°F by the artificial addition of heat during June, July and August, nor more than 4°F during the remainder of the year[2/]. The Texas Water Quality Requirements specify that a 1.5°F rise in the representative temperature above natural conditions is not to be exceeded during the summer, nor more than 4°F during fall, winter and spring. The area of the zone which will exceed the 1.5°F limit when the plant is in full operation is controversial but is estimated to be in the range of 600 to 2,200 acres. Measurable temperature increases will extend over a much larger area.

The impact of the expected water temperature increases on the shrimp nursery of Trinity Bay and other aquatic life is also a controversial subject. Increasing water temperatures have been found to be beneficial to some stages of shrimp development and detrimental to other stages.

Withdrawal of large quantities of cooling water is also expected to increase the dispersion of Houston Ship Channel pollution into Tabbs Bay, with attendant water quality degradation. The cooling system will thus provide a route for direct transmission of channel pollution to the relatively good quality water of upper Trinity Bay.

The Corps of Engineers model study evaluated the combined effects of the Cedar Bayou Power Plant, upstream development on the Trinity River, Wallisville Reservoir, and increased flow in the Houston Ship Channel on the dispersion of pollutants from the Ship Channel through-

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2/ Federal Water Pollution Control Administration, Water Quality Criteria, Report of National Technical Advisory Committee, April 1968, pp. 68-70.

out the estuary[3/]. The model study compared dispersion patterns under existing (1965) conditions with predicted dispersion patterns for proposed 1980 conditions of water use. A cooling water discharge of 3,500 cfs was used for the Cedar Bayou Power Plant. The relative concentrations of persistent pollutants would increase by as much as 600 percent in portions of upper Trinity Bay during low flow conditions. Flow-through time in the cooling water system is less than four days, indicating that the concentrations of degradable pollutants would also increase substantially. It would appear that increasing the power plant discharge to 5,000 cfs would further increase the concentration of pollutants.

Salinity concentrations in Tabbs Bay and upper Galveston Bay are higher than in upper Trinity Bay. The cooling water system will thus contribute to some increase in salinity levels in Trinity Bay. Evaporation from the cooling ponds will also slightly increase the salinity of the cooling water discharge. The combined effects of the cooling water discharge and reduced freshwater inflow from the Trinity River on salinity levels were evaluated by the model study. Predicted future increases in average salinity levels for both low-flow and high-flow periods are larger in the Trinity Bay area than any other area of the estuary. Since Trinity Bay is a prime shrimp nursery area and shrimp propagation is affected by salinity levels, the most significant changes in future salinity levels will come in an area where they can cause the most damage.

[3/] Bobb, W. H., and R. A. Boland, Jr., Galveston Bay Hurricane Surge Study, Technical Report H-69-12, July 1970, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

C. MORGAN POINT DEEPWATER PORT

With the exception of port facilities in Galveston and Texas City, almost all of the existing deepwater port facilities in the estuary are located on the landlocked portion of the Houston Ship Channel above Morgan Point. In this location, any vessel pollution, oil spills and waste discharges associated with operations of port facilities and ancillary industries may be somewhat diluted and dispersed by the time they reach the higher quality open waters of Galveston Bay.

The Port of Houston has announced plans to construct a new major deepwater port facility at the site of the existing shallow draft Barbour Terminal near Morgan Point. This location is immediately adjacent to the open waters of upper Galveston Bay. Any pollution from this facility could thus be carried directly to the Bay by wind currents and prevailing circulation patterns. The proximity of the port facility to the Cedar Bayou Channel and the cooling water intake of the Cedar Bayou Power Plant would provide an avenue for rapid transport of additional pollution to Trinity Bay.

The magnitude of the pollution hazard posed by the port facility will be primarily dependent upon the types of activities occurring at the port. As presently planned, the major port activity will be the handling of containerized cargo from large container ships and the loading and unloading of barges from barge carrying ships. This type of activity should generate minimal pollution except for vessel pollution caused by the incrased vessel activity in the area. Should the port also be used for the off-loading of cargo from deep-draft to shallow-draft vessels for transshipment on the area's shallow-draft channels, the potential for spills of oil and hazardous materials would be increased.

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APPENDIX A

Applicable Texas Water Quality Requirements For The Galveston Bay Area[1] And The Public Health Service Manual "Sanitation of Shellfish Growing Areas"

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[1] See Figure V-1 for Water Quality Zones established in the Galveston Bay Area.

GENERAL STATEMENT TEXAS WATER QUALITY REQUIREMENTS

The Texas Water Quality Act, through which the State of Texas expresses its interest in the quality of the waters in the state, sets forth the following statement of policy: "It is declared to be the policy of the State of Texas to maintain purity of the waters of the state consistent with the public health and public enjoyment thereof, the propagation and protection of fish and wildlife, including birds, mammals, and other terrestrial and aquatic life, the operation of existing industries, and the economic development of the state, and to that end to require the use of all reasonable methods to implement this policy."

The water quality requirements set forth herein have been developed under authority of State law in line with the foregoing statement of legislative policy and are considered to be in the best interests of the State of Texas. These water quality requirements, insofar as applicable to the interstate waters in Texas, are submitted to the United States Department of the Interior for approval as the water quality standards for such waters, in accordance with Section 10(c) of the Federal Water Pollution Control Act (33 U.S.C. 466g(c). The water quality requirements applicable to the intrastate waters in Texas are provided to the Federal Water Pollution Control Administration only for purposes related to the qualification of projects under the Federal construction grant program as authorized in Section 8 of the Act (33 U.S.C. 466(e).

In implementing the legislative policy expressed in the Texas Water Quality Act of 1967 and subject to the foregoing, it is the policy of the Texas Water Quality Board that the interstate waters in the State whose existing quality is better than the applicable water quality requirements described herein as of the date when these requirements become effective will as provided hereafter be maintained at their high quality, and no waste discharges may be made which will result in the lowering of the quality of these waters unless and until it has been demonstrated to the Texas Water Quality Board that the change is justifiable as a result of desirable economic or social development. Therefore, the Board will not authorize or approve any waste discharge which will result in the quality of any of the interstate waters in the State being reduced below the water quality standards without complying with the Federal and State laws applicable to the amendment of water quality standards. Anyone making a waste discharge from any industrial, public or private project or development which would constitute a new source of pollution or an increased source of pollution to any of the interstate waters in the State will be required, as part of the initial project design, to provide the highest and best degree of waste treatment available under existing technology consistent with the best practice in the particular field affected under the conditions applicable to the project or development. In the spirit of the Federal Water Pollution Control Act, the Board will keep the Department of the Interior informed on its activities and will furnish to the Department such reports, in such form, and containing such information as the Secretary of the Interior may from time to time reasonably require to carry out his functions under the Act. Additionally, the Board will consult and cooperate with the Department of the Interior on all matters affecting the Federal interest.

The Texas Water Plan presently being developed by the Texas Water Development Board is a flexible proposal for the administration of water resources to meet water needs for all purposes throughout the state to the year 2020 and beyond. The Plan, when complete, will propose a method of implementation in accordance with the statutory directive that the Plan be developed with "regard for the public interest for the entire state . . . in order that sufficient water will be available at reasonable cost to further the economic development of the entire state." The Texas Water Quality Requirements, or the Texas Water Quality Plan, is a companion plan to the Texas Water Plan.

The Wagstaff Act, passed in 1931, establishes the priority of uses as between applicants for permits to appropriate water from the same source of supply. The preferences of use in order of sequence are: (1) domestic and municipal, (2) industrial, (3) irrigation, (4) Mining and recovery of minerals, (5) hydroelectric power, (6) navigation, and (7) recreation. Cities are empowered to acquire the use of surface waters for domestic and municipal purposes from an appropriator who uses the water for a lower purpose, provided the appropriation from a lower use was perfected after the 1931 Wagstaff Act. Texas also has a dual riparian and appropriative rights system, which prevents the precise administration of the surface waters in the state as to particular uses, although the Texas Water Rights Adjudication Act, recently adopted by the Legislature, should alleviate this. The Texas Water Plan also envisions the transfer of waters across the face of the state to meet water needs, and this will affect the water quality requirements for those waters. The examples of water uses set forth on the water quality requirement pages following are indicators of the uses to which the water might reasonably be put. Water uses of a non-consumptive nature such as fishing, recreation, aesthetics, and navigation under some conditions may be recognized and provided for independently of statutory consumptive uses.

1. The surface waters of the State of Texas, for the purposes of this document, are divided into two categories, namely:

   A. Inland Waters - Those surface waters not subject to the ebb and flow of the tides.

   B. Tidal Waters - Those waters of the Gulf of Mexico within the jurisdiction of the State of Texas, bays and estuaries thereto, and those portions of the river systems which are subject to the ebb and flow of the tides, and to the intrusion of marine waters.

2. For inland waters, the proposed requirements are based on an evaluation of available data and reflect those quality conditions which can be attained in streams when there is a discernible flow in the stream. These requirements also apply to reservoirs, lakes and impoundments, bays and estuaries and other coastal waters of the state, except as provided in paragraph 7.

3. Sampling will be in accordance with fully recognized procedures. Samples must be representative of the receiving waters allowing time and distance for mixing.

4. The water quality requirements represent arithmetic average conditions over a period of one year, but maxima and minima for some parameters are shown where average values do not provide the necessary degree of understanding or regulatory base. The water quality requirements apply at approximately the mid-point of the zone with reasonable gradients applying toward zonal boundaries; where three consecutive samples taken in the regular course of surveillance activities reflect a water quality less than that shown in the water quality requirement, an investigation will be made to determine the cause of the lower quality water and the appropriate action to be taken.

5. The values established by the parameters in these water quality requirements relate to analytical procedures outlined in the latest edition of the "Standard Methods for the Examination of Water and Wastewater" as prepared and published jointly by the American Public Health Association, the American Water Works Association, and the Water Pollution Control Federation.

   In evaluating toxicity, bioassay techniques are to be selected suited for the particular purpose at hand.

   Where water quality requirements need supplementing to provide adequate water quality protection, such terms and conditions as may be necessary will be placed in permits for discharges of wastes.

   Taste and odor producing substances shall be limited to concentrations in the waters of the state that will not interfere with the production of potable water by reasonable water treatment methods, or impart unpalatable flavors to food fish, including shellfish, or result in offensive odors arising from the waters, or otherwise interfere with the reasonable use of the waters.

6. The suitability of water for irrigation will be based on the irrigation water classification system developed by the University of California at Davis and the U. S. Salinity Laboratory at Riverside, California. Class I irrigation water is desirable, and will be assumed wherever possible. Class II or Class III irrigation water may be satisfactory under conditions of soil, climate, irrigation practices, and crops where impairment and deterioration will not ensue.

   The SAR (sodium adsorption ratio) should not exceed 8 for waters safe for irrigation. Sampling and analytical procedures and schedules are not specified but will be as appropriate for adequate protection of irrigation waters.

   A resolution of the Texas State Department of Health applies as to the sanitary quality of irrigation waters.

7. Although temperature requirements are included in these water quality requirements, information on stream and bay temperatures and information on the effects of stream and bay temperatures on the state fisheries resource is inadequate on a statewide basis. Water uses requiring temperature control have not been inventoried and their intake water temperature needs are not known. The state has initiated a survey program to obtain adequate background data on water and waste temperatures. In addition, at Texas A & M University, under sponsorship of the Electric Utilities of Texas Committee on Water Quality, a research program has been initiated seeking to provide, from the fisheries standpoint, an acceptable basis for setting water temperature requirements. It is the intention of the Texas Water Quality Board when sufficient firm information is available, to review in full the water temperature requirements set herein as may be deemed appropriate. During this interim period, the temperature conditions shown in these water quality requirements will apply. No temperature

requirements apply to off-stream or privately owned reservoirs. The temperature requirements are intended to be read broadly and with judgment. Generally speaking, temperature requirements refer to the representative temperature throughout the entire body of water into which the waste discharge is made. The extent of the receiving body of water can only be defined on the basis of judgment and knowledge of existing conditions.

8. Water oriented recreation, including water contact sports, is a desirable use of the waters of the state everywhere. Water contact activities in natural waters are not opposed by the state health agency where routine sanitary surveys support such activities, and where, in addition, as a flexible guideline to be used in the light of conditions disclosed by the sanitary survey, the geometric means of the number of fecal coliform bacteria is less than 200 per hundred milliliters and not more than 10% of the samples during any thirty (30) day period exceed 400 fecal coliform bacteria per hundred milliliters. This policy is advisory only and in no way limits the responsibilities and authorities of local health agencies.

9. It is highly desirable for waters comprising the raw water supply to a public surface water treating plant that the total coliform bacteria should not exceed 100 per 100 milliliters and the fecal coliform bacteria should not exceed 20 per 100 milliliters. Nevertheless, raw water supplies to surface water treating plants shall not be deemed unsatisfactory where the total coliform orgainisms do not exceed 20,000 per 100 milliliters and the fecal coliform organisms do not exceed 2,000 per 100 milliliters. The evaluation of raw water supplies cannot be reduced to the simple counting of bacteria of any kind and the foregoing must be used with judgment and discretion and this paragraph is not intended to limit the responsibilities and authorities of responsible local governments or local health agencies.

10. Nothing in these water quality requirements limits the authority of the Commissioner of Health of the State of Texas to take such public health protective measures as he may deem necessary.

11. It is the policy of the State of Texas, acting through the Texas Water Quality Board, to require primary and secondary

treatment and disinfection (except for oxidation pond effluents) at all facilities serving the general public and which treat domestic sanitary wastes. Treatment or control of industrial wastes is equally as important as the treatment or control of municipal (domestic) wastes. It is the policy of the Texas Water Quality Board to require a comparably high standard of treatment or control of industrial wastes being discharged to the waters of the State. Therefore, anyone making a waste discharge from any industrial, public or private project or development which would constitute a new source of pollution to any of the waters in the State will be required, as part of the initial project design, to provide the highest and best degree of waste treatment available under existing technology consistent with the best practice in the particular field affected under the conditions applicable to the project or development.

12. The general water quality requirements listed below are applicable to all waters at all times:

    A. Essentially free of floating debris and settleable suspended solids conducive to the production of putrescible sludge deposits or sediment layers which would adversely affect benthic biota, or other lawful uses.

    B. Essentially free of settleable suspended solids conducive to changes in the flow character of stream bottoms, to the untimely filling of reservoirs and lakes, and which might result in unnecessary dredging costs.

    C. The surface waters in the state shall be maintained in an aesthetically attractive condition.

    D. There shall be no substantial visible contrast to the natural appearance of the receiving waters so far as is feasible after wastes receive the best practicable treatment or control.

    E. There shall be no substantial increase in turbidity due to waste discharges.

GULF OF MEXICO AT GALVESTON

0901

(THE GENERAL STATEMENT IS AN INTEGRAL PART OF THE FOLLOWING REQUIREMENTS.)

A.	Chloride, average not to exceed	20,000 mg/l
B.	Sulphate average not to exceed	3,000 mg/l
C.	Filterable Residue, average not to exceed (Total Dissolved Solids)	45,000 mg/l
D.	B.O.D., average not to exceed	1.0 mg/l
E.	Dissolved Oxygen, not less than	7.0 mg/l
F.	pH Range	7.0-9.0
G.	MPN, logarithmic average not more than	5.0/100 ml

H. Temperature (See General Statement). Fall, winter, and spring, not to exceed a 4 F rise in the representative temperature above natural conditions. Summer, not to exceed a 1.5 F. rise in the representative temperature above natural conditions.

This temperature requirement is a requirement of the Federal Water Pollution Control Administration.

I. Toxicity and Toxic Materials – These waters shall not exhibit either acute or chronic toxicity (or other harmful effect) to human, animal, or aquatic life to such an extent as to interfere with uses of the waters. (See General Statement)

J. Free or Floating Oil – Substantially free from oil.

K. Foaming or Frothing Material – None of a persistent nature.

L. Does not apply to Gulf Waters.

M. Radioactive Materials – Levels of ionizing radiation and radioactive materials of all kinds, from both dissolved and suspended matter, shall be regulated by the Texas Radiation Control Act, Article 4590 (f), Revised Civil Statutes of Texas, and the Texas Regulations for Control of Radiation issued thereunder.

GULF OF MEXICO AT GALVESTON

0901

Water Quality is deemed suitable for the following uses among others:

- Contact Recreation
- Non-Contact Recreation
- Propagation of Fish and Wildlife
- Fishing
- Aesthetics
- Navigation
- Industrial Cooling Water

Known water uses:

- Contact Recreation
- Non-Contact Recreation
- Propagation of Fish and Wildlife
- Fishing
- Aesthetics
- Navigation

TRINITY RIVER TIDAL

0902

(THE GENERAL STATEMENT IS AN INTEGRAL PART OF THE FOLLOWING REQUIREMENTS.)

These requirements relate to the surface water layer. The salinity of the underlying saline waters will approach that of the contiguous bay or coastal zone. Where there is no surface water layer or where mixing has occurred, judgment must be applied. In some streams, salt water barriers may prevent the intrusion of marine waters.

A.	Chloride, average not to exceed	6,000 mg/l
B.	Sulphate, average not to exceed	500 mg/l
C.	Filterable Residue, average not to exceed (Total Dissolved Solids)	10,000 mg/l
D.	B.O.D., average not to exceed	4.0 mg/l
E.	Dissolved Oxygen, not less than	6.0 mg/l
F.	pH Range	7.0-9.0
G.	MPN, logarithmic average not more than	1,000 /100 ml

H. Temperature (See General Statement). Fall, winter, and spring, not to exceed a 4°F rise in the representative temperature above natural conditions. Summer, not to exceed a 1.5°F rise in the representative temperature above natural conditions.

This temperature requirement is a requirement of the Federal Water Pollution Control Administration.

I. Toxicity and Toxic Materials – These waters shall not exhibit either acute or chronic toxicity (or other harmful effect) to human, animal, or aquatic life to such an extent as to interfere with uses of the waters. (See General Statement)

J. Free or Floating Oil – Substantially free from oil.

K. Foaming or Frothing Material – None of a persistent nature.

L. Other – The control of other substances not heretofore mentioned will be guided by the U.S. Public Health Service manual "Sanitation of Shellfish Growing Areas", 1965 revision.

M. Radioactive Materials – Levels of ionizing radiation and radioactive materials of all kinds, from both dissolved and suspended matter, shall be regulated by the Texas Radiation Control Act, Article 4590 (f), Revised Civil Statutes of Texas, and the Texas Regulations for Control of Radiation issued thereunder.

TRINITY RIVER TIDAL

0902

Water Quality is deemed suitable for the following uses among others:

- Contact Recreation
- Non-Contact Recreation
- Propagation of Fish and Wildlife
- Fishing
- Aesthetics
- Navigation
- Industrial Cooling Water

Known water uses:

- Contact Recreation
- Non-Contact Recreation
- Propagation of Fish and Wildlife
- Fishing
- Aesthetics
- Navigation

SAN JACINTO RIVER TIDAL
(ALSO SEE TWQB ORDER 65-9)

0903

(THE GENERAL STATEMENT IS AN INTEGRAL PART OF THE FOLLOWING REQUIREMENTS.)

These requirements relate to the surface water layer. The salinity of the underlying saline waters will approach that of the contiguous bay or coastal zone. Where there is no surface water layer or where mixing has occurred, judgment must be applied. In some streams, salt water barriers may prevent the intrusion of marine waters.

A.	Chloride, average not to exceed	10,000	mg/l
B.	Sulphate, average not to exceed	1,000	mg/l
C.	Filterable Residue, average not to exceed (Total Dissolved Solids)	20,000	mg/l
D.	B.O.D., average not to exceed	2.0	mg/l
E.	Dissolved Oxygen, not less than	4.0	mg/l
F.	pH Range	6.2-8.5	
G.	MPN, logarithmic average not more than	50/100 ml	

H. Temperature (See General Statement). Fall, winter, and spring, not to exceed a 4°F rise in the representative temperature above natural conditions. Summer, not to exceed a 1.5°F rise in the representative temperature above natural conditions.

This temperature requirement is a requirement of the Federal Water Pollution Control Administration.

I. Toxicity and Toxic Materials – These waters shall not exhibit either acute or chronic toxicity (or other harmful effect) to human, animal, or aquatic life to such an extent as to interfere with uses of the waters. (See General Statement)

J. Free or Floating Oil – Substantially free from oil.

K. Foaming or Frothing Material – None of a persistent nature.

L. Other – The control of other substances not heretofore mentioned will be guided by the U.S. Public Health Service manual "Sanitation of Shellfish Growing Areas", 1965 revision.

M. Radioactive Materials – Levels of ionizing radiation and radioactive materials of all kinds, from both dissolved and suspended matter, shall be regulated by the Texas Radiation Control Act, Article 4590 (f), Revised Civil Statutes of Texas, and the Texas Regulations for Control of Radiation issued thereunder.

SAN JACINTO RIVER TIDAL
(ALSO SEE TWQB ORDER 65-9)

0903

Water Quality is deemed suitable for the following uses among others:

- Contact Recreation
- Non-Contact Recreation
- Propagation of Fish and Wildlife
- Fishing
- Aesthetics
- Navigation
- Industrial Cooling Water

Known water uses:

- Contact Recreation
- Non-Contact Recreation
- Propagation of Fish and Wildlife
- Fishing
- Aesthetics
- Navigation
- Industrial Cooling Water

HOUSTON SHIP CHANNEL
(TURNING BASIN AREA)

0904

(THE GENERAL STATEMENT IS AN INTEGRAL PART OF THE FOLLOWING REQUIREMENTS.)

These requirements relate to the surface water layer. The salinity of the underlying saline waters will approach that of the contiguous bay or coastal zone. Where there is no surface water layer or where mixing has occurred, judgment must be applied. In some streams, salt water barriers may prevent the intrusion of marine waters.

A.	Chloride, average not to exceed	4,000 mg/l
B.	Sulphate, average not to exceed	600 mg/l
C.	Filterable Residue, average not to exceed (Total Dissolved Solids)	9,500 mg/l
D.	B.O.D., average not to exceed	7.0 mg/l
E.	Dissolved Oxygen, not less than	1.5 mg/l
F.	pH Range	6.0-8.5
G.	MPN, logarithmic average not more than	100,000 /100 ml

H. Temperature (See General Statement). Fall, winter, and spring, not to exceed a 4°F. rise in the representative temperature above natural conditions. Summer, not to exceed a 1.5°F. rise in the representative temperature above natural conditions.

This temperature requirement is a requirement of the Federal Water Pollution Control Administration.

I. Toxicity and Toxic Materials – These waters shall not exhibit either acute or chronic toxicity (or other harmful effect) to human, animal, or aquatic life to such an extent as to interfere with uses of the waters. (See General Statement)

J. Free or Floating Oil – Substantially free from oil.

K. Foaming or Frothing Material – None of a persistent nature.

L. Does not apply.

M. Radioactive Materials – Levels of ionizing radiation and radioactive materials of all kinds, from both dissolved and suspended matter, shall be regulated by the Texas Radiation Control Act, Article 4590 (f), Revised Civil Statutes of Texas, and the Texas Regulations for Control of Radiation issued thereunder.

HOUSTON SHIP CHANNEL
(TURNING BASIN AREA)

0904

Water Quality is deemed suitable for the following uses among others:

- Aesthetics
- Navigation
- Industrial Cooling Water

Known water uses:

- Navigation
- Industrial Cooling Water

HOUSTON SHIP CHANNEL–SAN JACINTO MONUMENT TO TURNING BASIN

(MEASURED AT SAN JACINTO MONUMENT TO CONFORM WITH TWQB ORDER 65-9)

0905

(THE GENERAL STATEMENT IS AN INTEGRAL PART OF THE FOLLOWING REQUIREMENTS.)

These requirements relate to the surface water layer. The salinity of the underlying saline waters will approach that of the contiguous bay or coastal zone. Where there is no surface water layer or where mixing has occurred, judgment must be applied. In some streams, salt water barriers may prevent the intrusion of marine waters.

A.	Chloride, average not to exceed	7,000	mg/l
B.	Sulphate, average not to exceed	1,000	mg/l
C.	Filterable Residue, average not to exceed (Total Dissolved Solids)	16,000	mg/l
D.	B.O.D., average not to exceed	5.0	mg/l
E.	Dissolved Oxygen, not less than	2.0	mg/l
F.	pH Range	6.0-8.5	
G.	MPN, logarithmic average not more than	10,000 /100 ml	

H. Temperature (See General Statement). Fall, winter, and spring, not to exceed a 4°F rise in the representative temperature above natural conditions. Summer, not to exceed a 1.5°F rise in the representative temperature above natural conditons.

This temperature requirement is a requirement of the Federal Water Pollution Control Administration.

I. Toxicity and Toxic Materials – These waters shall not exhibit either acute or chronic toxicity (or other harmful effect) to human, animal, or aquatic life to such an extent as to interfere with uses of the waters. (See General Statement)

J. Free or Floating Oil – Substantially free from oil.

K. Foaming or Frothing Material – None of a persistent nature.

L. Other – The control of other substances not heretofore mentioned will be guided by the U.S. Public Health Service manual "Sanitation of Shellfish Growing Areas", 1965 revision.

M. Radioactive Materials – Levels of ionizing radiation and radioactive materials of all kinds, from both dissolved and suspended matter, shall be regulated by the Texas Radiation Control Act, Article 4590 (f), Revised Civil Statutes of Texas, and the Texas Regulations for Control of Radiation issued thereunder.

HOUSTON SHIP CHANNEL–SAN JACINTO MONUMENT TO TURNING BASIN

(MEASURED AT SAN JACINTO MONUMENT TO CONFORM WITH TWQB ORDER 65-9)

0905

Water Quality is deemed suitable for the following uses among others:

Non-Contact Recreation
Aesthetics
Navigation
Industrial Cooling Water

Known water uses:

Non-Contact Recreation
Aesthetics
Navigation
Industrial Cooling Water

HOUSTON SHIP CHANNEL–MORGANS POINT TO SAN JACINTO MONUMENT

(MEASURED AT MORGANS POINT IN CONFORMANCE WITH TWQB ORDER 65-9)

0906

(THE GENERAL STATEMENT IS AN INTEGRAL PART OF THE FOLLOWING REQUIREMENTS.)

These requirements relate to the surface water layer. The salinity of the underlying saline waters will approach that of the contiguous bay or coastal zone. Where there is no surface water layer or where mixing has occurred, judgment must be applied. In some streams, salt water barriers may prevent the intrusion of marine waters.

A.	Chloride, average not to exceed	10,000 mg/l
B.	Sulphate, average not to exceed	1,000 mg/l
C.	Filterable Residue, average not to exceed (Total Dissolved Solids)	20,000 mg/l
D.	B.O.D., average not to exceed	2.0 mg/l
E.	Dissolved Oxygen, not less than	4.0 mg/l
F.	pH Range	6.2-8.5
G.	MPN, logarithmic average not more than	50/100 ml

H. Temperature (See General Statement). Fall, winter, and spring, not to exceed a 4°F rise in the representative temperature above natural conditions. Summer, not to exceed a 1.5°F rise in the representative temperature above natural conditions.

This temperature requirement is a requirement of the Federal Water Pollution Control Administration.

I. Toxicity and Toxic Materials – These waters shall not exhibit either acute or chronic toxicity (or other harmful effect) to human, animal, or aquatic life to such an extent as to interfere with uses of the waters. (See General Statement)

J. Free of Floating Oil – Substantially free from oil.

K. Foaming or Frothing Material – None of a persistent nature.

L. Other – The control of other substances not heretofore mentioned will be guided by the U.S. Public Health Service manual "Sanitation of Shellfish Growing Areas", 1965 revision.

M. Radioactive Materials – Levels of ionizing radiation and radioactive materials of all kinds, from both dissolved and suspended matter, shall be regulated by the Texas Radiation Control Act, Article 4590 (f) Revised Civil Statutes of Texas, and the Texas Regulations for Control of Radiation issued thereunder.

HOUSTON SHIP CHANNEL–MORGANS POINT TO SAN JACINTO MONUMENT

(MEASURED AT MORGANS POINT IN CONFROMANCE WITH TWQB ORDER 65-9)

0906

Water Quality is deemed suitable for the following uses among others:

Contact Recreation
Non-Contact Recreation
Propagation of Fish and Wildlife
Fishing
Aesthetics
Navigation
Industrial Cooling Water

Known water uses:

Contact Recreation
Non-Contact Recreation
Propagation of Fish and Wildlife
Fishing
Aesthetics
Navigation
Industrial Cooling Water

CLEAR LAKE
(SEWAGE EFFLUENTS DIVERTED)

0907

(THE GENERAL STATEMENT IS AN INTEGRAL PART OF THE FOLLOWING REQUIREMENTS.)

A.	Chloride, average not to exceed	
B.	Sulphate, average not to exceed	5,000 mg/l
C.	Filterable Residue, average not to exceed	700 mg/l
	(Total Dissolved Solids)	
D.	B.O.D., average not to exceed	12,000 mg/l
E.	Dissolved Oxygen, not less than	3.0 mg/l
F.	pH Range	6.0 mg/l
G.	MPN, logarithmic average not more than	7.0-9.0
		70/100 ml

H. Temperature (See General Statement). Fall, winter, and spring, not to exceed a 4°F rise in the representative temperature above natural conditions. Summer, not to exceed a 1.5°F rise in the representative temperature above natural conditions.

This temperature requirement is a requirement of the Federal Water Pollution Control Administration.

I. Toxicity and Toxic Materials – These waters shall not exhibit either acute or chronic toxicity (or other harmful effect) to human, animal, or aquatic life to such an extent as to interfere with uses of the waters. (See General Statement)

J. Free or Floating Oil – Substantially free from oil.

K. Foaming or Frothing Material – None of a persistent nature.

L. Other – The control of other substances not heretofore mentioned will be guided by the U.S. Public Health Service manual "Sanitation of Shellfish Growing Areas", 1965 revision. Where waters are not shellfish growing areas, it is required only that waters entering or contiguous to a shellfish growing area not interfere with the shellfish growing area.

M. Radioactive Materials – Levels of ionizing radiation and radioactive materials of all kinds, from both dissolved and suspended matter, shall be regulated by the Texas Radiation Control Act, Article 4590 (f), Revised Civil Statutes of Texas, and the Texas Regulations for Control of Radiation issued thereunder.

CLEAR LAKE
(SEWAGE EFFLUENTS DIVERTED)

0907

Water Quality is deemed suitable for the following uses among others:

Contact Recreation
Non-Contact Recreation
Propagation of Fish and Wildlife
Fishing
Aesthetics
Navigation
Industrial Cooling Water

Known water uses:

Contact Recreation
Non-Contact Recreation
Propagation of Fish and Wildlife
Fishing
Aesthetics
Navigation

TEXAS CITY SHIP CHANNEL
(MONITORED AT GALVESTON BAY SURVEY STATION A-92, NORTHWEST OF SNAKE ISLAND)

0908

(THE GENERAL STATEMENT IS AN INTEGRAL PART OF THE FOLLOWING REQUIREMENTS.)

These requirements relate to the surface water layer. The salinity of the underlying saline waters will approach that of the contiguous bay or coastal zone. Where there is no surface water layer or where mixing has occurred, judgment must be applied. In some streams, salt water barriers may prevent the intrusion of marine waters.

A.	Chloride, average not to exceed	17,000 mg/l
B.	Sulphate, average not to exceed	2,000 mg/l
C.	Filterable Residue, average not to exceed (Total Dissolved Solids)	35,000 mg/l
D.	B.O.D., average not to exceed	8.0 mg/l
E.	Dissolved Oxygen, not less than	3.0 mg/l
F.	pH Range	7.0-9.0
G.	MPN, logarithmic average not more than	1,000 /100 ml

H. Temperature (See General Statement). Fall, winter, and spring, not to exceed a 4°F rise in the representative temperature above natural conditions. Summer, not to exceed a 1.5°F rise in the representative temperature above natural conditions.

This temperature requirement is a requirement of the Federal Water Pollution Control Administration.

I. Toxicity and Toxic Materials – These waters shall not exhibit either acute or chronic toxicity (or other harmful effect) to human, animal, or aquatic life to such an extent as to interfere with uses of the waters. (See General Statement)

J. Free or Floating Oil – Substantially free from oil.

K. Foaming or Frothing Material – None of a persistent nature.

L. Other – The control of other substances not heretofore mentioned will be guided by the U.S. Public Health Service manual "Sanitation of Shellfish Growing Areas", 1965 revision.

M. Radioactive Materials – Levels of ionizing radiation and radioactive materials of all kinds, from both dissolved and suspended matter, shall be regulated by the Texas Radiation Control Act, Article 4590 (f), Revised Civil Statutes of Texas, and the Texas Regulations for Control of Radiation issued thereunder.

TEXAS CITY SHIP CHANNEL
(MONITORED AT GALVESTON BAY SURVEY STATION A-92, NORTHWEST OF SNAKE ISLAND)

0908

Water Quality is deemed suitable for the following uses among others:

Contact Recreation
Non-Contact Recreation
Propagation of Fish and Wildlife
Fishing
Aesthetics
Navigation
Industrial Cooling Water

Known water uses:

Contact Recreation
Non-Contact Recreation
Propagation of Fish and Wildlife
Fishing
Aesthetics
Navigation

EAST BAY

1101

(THE GENERAL STATEMENT IS AN INTEGRAL PART OF THE FOLLOWING REQUIREMENTS.)

A.	Chloride, average not to exceed	12,000 mg/l
B.	Sulphate, average not to exceed	1,200 mg/l
C.	Filterable Residue, average not to exceed (Total Dissolved Solids)	25,000 mg/l
D.	B.O.D., average not to exceed	3.0 mg/l
E.	Dissolved Oxygen, not less than	6.0 mg/l
F.	pH Range	7.0-9.0
G.	MPN, logarithmic average not more than	70/100 ml

H. Temperature (See General Statement). Fall, winter, and spring, not to exceed a 4°F. rise in the representative temperature above natural conditions. Summer, not to exceed a 1.5°F. rise in the representative temperature above natural conditions.

This temperature requirement is a requirement of the Federal Water Pollution Control Administration.

I. Toxicity and Toxic Materials – These waters shall not exhibit either acute or chronic toxicity (or other harmful effect) to human, animal, or aquatic life to such an extent as to interfere with uses of the waters. (See General Statement)

J. Free or Floating Oil – Substantially free from oil.

K. Foaming or Frothing Material – None of a persistent nature.

L. Other – The control of other substances not heretofore mentioned will be guided by the U.S. Public Health Service manual "Sanitation of Shellfish Growing Areas", 1965 revision. Where waters are not shellfish growing areas, it is required only that waters entering or contiguous to a shellfish growing area not interfere with the shellfish growing area.

M. Radioactive Materials – Levels of ionizing radiation and radioactive materials of all kinds, from both dissolved and suspended matter, shall be regulated by the Texas Radiation Control Act, Article 4590 (f), Revised Civil Statutes of Texas, and the Texas Regulations for Control of Radiation issued thereunder.

EAST BAY

1101

Water Quality is deemed suitable for the following uses among others:

- Contact Recreation
- Non-Contact Recreation
- Propagation of Fish and Wildlife
- Fishing
- Aesthetics
- Navigation
- Industrial Cooling Water

Known water uses:

- Contact Recreation
- Non-Contact Recreation
- Propagation of Fish and Wildlife
- Fishing
- Aesthetics
- Navigation

GALVESTON BAY

(EAST OF HOUSTON SHIP CHANNEL, BOUNDED BY CHANNEL MARKER 68, FISHER SHOALS DAY BEACON #1, LONE OAK BAYOU, SMITH POINT, HANNA REEF AND BOLIVAR PENINSULA)

1102

(THE GENERAL STATEMENT IS AN INTEGRAL PART OF THE FOLLOWING REQUIREMENTS.)

A.	Chloride, average not to exceed	12,000 mg/l
B.	Sulphate, average not to exceed	1,200 mg/l
C.	Filterable Residue, average not to exceed (Total Dissolved Solids)	25,000 mg/l
D.	B.O.D., average not to exceed	4.0 mg/l
E.	Dissolved Oxygen, not less than	6.0 mg/l
F.	pH Range	7.0-9.0
G.	MPN, logarithmic average not more than	70/100 ml

H. Temperature (See General Statement). Fall, winter, and spring, not to exceed a 4°F. rise in the representative temperature above natural conditions. Summer, not to exceed a 1.5°F. rise in the representative temperature above natural conditions.

This temperature requirement is a requirement of the Federal Water Pollution Control Administration.

I. Toxicity and Toxic Materials – These waters shall not exhibit either acute or chronic toxicity (or other harmful effect) to human, animal, or aquatic life to such an extent as to interfere with uses of the waters. (See General Statement)

J. Free or Floating Oil – Substantially free from oil.

K. Foaming or Frothing Material – None of a persistent nature.

L. Other – The control of other substances not heretofore mentioned will be guided by the U.S. Public Health Service manual "Sanitation of Shellfish Growing Areas", 1965 revision. Where waters are not shellfish growing areas, it is required only that waters entering or contiguous to a shellfish growing area not interfere with the shellfish growing area.

M. Radioactive Materials – Levels of ionizing radiation and radioactive materials of all kinds, from both dissolved and suspended matter, shall be regulated by the Texas Radiation Control Act, Article 4590 (f), Revised Civil Statutes of Texas, and the Texas Regulations for Control of Radiation issued thereunder.

GALVESTON BAY

(EAST OF HOUSTON SHIP CHANNEL. BOUNDED BY CHANNEL MARKER 68, FISHER SHOALS DAY BEACON #1, LONE OAK BAYOU, SMITH POINT, HANNA REEF AND BOLIVAR PENINSULA

1102

Water Quality is deemed suitable for the following uses among others:

- Contact Recreation
- Non-Contact Recreation
- Propagation of Fish and Wildlife
- Fishing
- Aesthetics
- Navigation
- Industrial Cooling Water

Known water uses:

- Contact Recreation
- Non-Contact Recreation
- Propagation of Fish and Wildlife
- Fishing
- Aesthetics
- Navigation

TRINITY BAY AND GALVESTON BAY

(EAST OF HOUSTON SHIP CHANNEL AND NORTH OF CHANNEL MARKER 68 AND FISHER SHOALS DAY BEACON #1)

1103

(THE GENERAL STATEMENT IS AN INTEGRAL PART OF THE FOLLOWING REQUIREMENTS.)

A.	Chloride, average not to exceed	10,000 mg/l
B.	Sulphate, average not to exceed	700 mg/l
C.	Filterable Residue, average not to exceed (Total Dissolved Solids)	20,000 mg/l
D.	B.O.D., average not to exceed	5.0 mg/l
E.	Dissolved Oxygen, not less than	5.0 mg/l
F.	pH Range	7.0-9.0
G.	MPN, logarithmic average not more than	70/100 ml

H. Temperature (See General Statement). Fall, winter, and spring, not to exceed a 4°F. rise in the representative temperature above natural conditions. Summer, not to exceed a 1.5°F. rise in the representative temperature above natural conditions.

This temperature requirement is a requirement of the Federal Water Pollution Control Administration.

I. Toxicity and Toxic Materials – These waters shall not exhibit either acute or chronic toxicity (or other harmful effect) to human, animal, or aquatic life to such an extent as to interfere with uses of the waters. (See General Statement)

J. Free or Floating Oil – Substantially free from oil.

K. Foaming or Frothing Material – None of a persistent nature.

L. Other – The control of other substances not heretofore mentioned will be guided by the U.S. Public Health Service manual "Sanitation of Shellfish Growing Areas", 1965 revision. Where waters are not shellfish growing areas, it is required only that waters entering or contiguous to a shellfish growing area not interfere with the shellfish growing area.

M. Radioactive Materials – Levels of ionizing radiation and radioactive materials of all kinds, from both dissolved and suspended matter, shall be regulated by the Texas Radiation Control Act, Article 4590 (f), Revised Civil Statutes of Texas, and the Texas Regulations for Control of Radiation issued thereunder.

TRINITY BAY AND GALVESTON BAY

(EAST OF HOUSTON SHIP CHANNEL AND NORTH OF CHANNEL MARKER 68 AND FISHER SHOALS DAY BEACON #1)

1103

Water Quality is deemed suitable for the following uses among others:

- Contact Recreation
- Non-Contact Recreation
- Propagation of Fish and Wildlife
- Fishing
- Aesthetics
- Navigation
- Industrial Cooling Water

Known water uses:

- Contact Recreation
- Non-Contact Recreation
- Propagation of Fish and Wildlife
- Fishing
- Aesthetics
- Navigation
- Industrial Cooling Water

GALVESTON BAY
(WEST OF THE HOUSTON SHIP CHANNEL)

1104

(THE GENERAL STATEMENT IS AN INTEGRAL PART OF THE FOLLOWING REQUIREMENTS.)

A.	Chloride, average not to exceed	12,000 mg/l
B.	Sulphate, average not to exceed	1,500 mg/l
C.	Filterable Residue, average not to exceed (Total Dissolved Solids)	25,000 mg/l
D.	B.O.D., average not to exceed	6.0 mg/l
E.	Dissolved Oxygen, not less than	5.0 mg/l
F.	pH Range	7.0-9.0
G.	MPN, logarithmic average not more than	70/100 ml

H. Temperature (See General Statement). Fall, winter, and spring, not to exceed a 4°F rise in the representative temperature above natural conditions. Summer, not to exceed a 1.5°F rise in the representative temperature above natural conditions.

This temperature requirement is a requirement of the Federal Water Pollution Control Administration.

I. Toxicity and Toxic Materials – These waters shall not exhibit either acute or chronic toxicity (or other harmful effect) to human, animal, or aquatic life to such an extent as to interfere with uses of the waters. (See General Statement)

J. Free or Floating Oil – Substantially free from oil.

K. Foaming or Frothing Material – None of a persistent nature.

L. Other – The control of other substances not heretofore mentioned will be guided by the U.S. Public Health Service manual "Sanitation of Shellfish Growing Areas", 1965 revision. Where waters are not shellfish growing areas, it is required only that waters entering or contiguous to a shellfish growing area not interfere with the shellfish growing area.

M. Radioactive Materials – Levels of ionizing radiation and radioactive materials of all kinds, from both dissolved and suspended matter, shall be regulated by the Texas Radiation Control Act, Article 4590 (f), Revised Civil Statutes of Texas, and the Texas Regulations for Control of Radiation issued thereunder.

GALVESTON BAY
(WEST OF THE HOUSTON SHIP CHANNEL)

1104

Water Quality is deemed suitable for the following uses among others:

- Contact Recreation
- Non-Contact Recreation
- Propagation of Fish and Wildlife
- Fishing
- Aesthetics
- Navigation
- Industrial Cooling Water

Known water uses:

- Contact Recreation
- Non-Contact Recreation
- Propagation of Fish and Wildlife
- Fishing
- Aesthetics
- Navigation
- Industrial Cooling Water

WEST BAY
(EAST OF KARANKAWA REEF)

1105

(THE GENERAL STATEMENT IS AN INTEGRAL PART OF THE FOLLOWING REQUIREMENTS.)

A.	Chloride, average not to exceed	16,000 mg/l
B.	Sulphate, average not to exceed	2,000 mg/l
C.	Filterable Residue, average not to exceed (Total Dissolved Solids)	32,000 mg/l
D.	B.O.D., average not to exceed	3.0 mg/l
E.	Dissolved Oxygen, not less than	5.0 mg/l
F.	pH Range	7.0-9.0
G.	MPN, logarithmic average not more than	70/100 ml

H. Temperature (See General Statement). Fall, winter, and spring, not to exceed a 4°F. rise in the representative temperature above natural conditions. Summer, not to exceed a 1.5°F. rise in the representative temperature above natural conditions.

This temperature requirement is a requirement of the Federal Water Pollution Control Administration.

I. Toxicity and Toxic Materials – These waters shall not exhibit either acute or chronic toxicity (or other harmful effect) to human, animal, or aquatic life to such an extent as to interfere with uses of the waters. (See General Statement)

J. Free or Floating Oil – Substantially free from oil.

K. Foaming or Frothing Material – None of a persistent nature.

L. Other – The control of other substances not heretofore mentioned will be guided by the U.S. Public Health Service manual "Sanitation of Shellfish Growing Areas", 1965 revision. Where waters are not shellfish growing areas, it is required only that waters entering or contiguous to a shellfish growing area not interfere with the shellfish growing area.

M. Radioactive Materials – Levels of ionizing radiation and radioactive materials of all kinds, from both dissolved and suspended matter, shall be regulated by the Texas Radiation Control Act, Article 4590 (f), Revised Civil Statutes of Texas, and the Texas Regulations for Control of Radiation issued thereunder.

WEST BAY

(EAST OF KARANKAWA REEF)

1105

Water Quality is deemed suitable for the following uses among others:

Contact Recreation
Non-Contact Recreation
Propagation of Fish and Wildlife
Fishing
Aesthetics
Navigation
Industrial Cooling Water

Known water uses:

Contact Recreation
Non-Contact Recreation
Propagation of Fish and Wildlife
Fishing
Aesthetics
Navigation

WEST BAY
(WEST OF KARANKAWA REEF)

1106

(THE GENERAL STATEMENT IS AN INTEGRAL PART OF THE FOLLOWING REQUIREMENTS.)

A.	Chloride, average not to exceed	16,000 mg/l
B.	Sulphate, average not to exceed	2,000 mg/l
C.	Filterable Residue, average not to exceed (Total Dissolved Solids)	32,000 mg/l
D.	B.O.D., average not to exceed	2.5 mg/l
E.	Dissolved Oxygen, not less than	6.0 mg/l
F.	pH Range	7.0-9.0
G.	MPN, logarithmic average not more than	70/100 ml

H. Temperature (See General Statement). Fall, winter, and spring, not to exceed a 4°F. rise in the representative temperature above natural conditions. Summer, not to exceed a 1.5°F. rise in the representative temperature above natural conditions.

This temperature requirement is a requirement of the Federal Water Pollution Control Administration.

I. Toxicity and Toxic Materials – These waters shall not exhibit either acute or chronic toxicity (or other harmful effect) to human, animal, or aquatic life to such an extent as to interfere with uses of the waters. (See General Statement)

J. Free or Floating Oil – Substantially free from oil.

K. Foaming or Frothing Material – None of a persistent nature.

L. Other – The control of other substances not heretofore mentioned will be guided by the U.S. Public Health Service manual "Sanitation of Shellfish Growing Areas", 1965 revision. Where waters are not shellfish growing areas, it is required only that water entering or contiguous to a shellfish growing area not interfere with the shellfish growing area.

M. Radioactive Materials – Levels of ionizing radiation and radioactive materials of all kinds, from both dissolved and suspended matter, shall be regulated by the Texas Radiation Control Act, Article 4590 (f), Revised Civil Statutes of Texas, and the Texas Regulations for Control of Radiation issued thereunder.

WEST BAY

(WEST OF KARANKAWA REEF)

1106

Water Quality is deemed suitable for the following uses among others:

- Contact Recreation
- Non-Contact Recreation
- Propagation of Fish and Wildlife
- Fishing
- Aesthetics
- Navigation
- Industrial Cooling Water

Known water uses:

- Contact Recreation
- Non-Contact Recreation
- Propagation of Fish and Wildlife
- Fishing
- Aesthetics
- Navigation

National Shellfish Sanitation Program
Manual of Operations

Part I

Sanitation of Shellfish Growing Areas

1965 Revision

Edited by
Leroy S. Houser, Sanitarian Director

1798

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

Division of Environmental Engineering and Food Protection
Shellfish Sanitation Branch
Washington, D.C. 20201

This is part I of two companion volumes published by the Public Health Service with titles and publication numbers as follows:

National Shellfish Sanitation Program

Public Health Service Publication No. 33
(Revised 1965) Part I—Sanitation of
Shellfish Growing Areas

Public Health Service Publication No. 33
(Revised 1965) Part II—Sanitation of the
Harvesting and Processing of Shellfish

This is a revised edition published previously under the title: Cooperative Program for the Certification of Interstate Shellfish Shippers, Part I, Sanitation of Shellfish Growing Areas, 1962 Revision.

PUBLIC HEALTH SERVICE PUBLICATION NO. 33
Part I — Revised 1965

LIST OF PREVIOUS EDITIONS OF MANUAL OF OPERATIONS FOR NATIONAL SHELLFISH SANITATION PROGRAM—NOW SUPERSEDED

1925. Supplement No. 53 to Public Health Reports November 6, 1925 "Report of Committee on Sanitary Control of the Shellfish Industry in the United States".

1937. U.S. Public Health Service Minimum Requirements for Approval of State Shellfish Control Measures and Certification for Shippers in Interstate Commerce (Revised October 1937).

1946. Manual of Recommended Practice for Sanitary Control of the Shellfish Industry Recommended by the U.S. Public Health Service (Public Health Bulletin No. 295).

1957. Manual of Recommended Practice for Sanitary Control of the Shellfish Industry (Part II: Sanitation of the Harvesting and Processing of Shellfish). Printed as Part II of Public Health Service Publication No. 33.

1959. Manual of Recommended Practice for Sanitary Control of the Shellfish Industry (Part I: Sanitation of Shellfish Growing Areas). Printed as Part I of Public Health Service Publication No. 33.

1962. Cooperative Program for the Certification of Interstate Shellfish Shippers, Part II, Sanitation of the Harvesting and Processing of Shellfish. (Printed as Part II of Public Health Service Publication No. 33.)

1962. Cooperative Program for the Certification of Interstate Shellfish Shippers, Part I, Sanitation of Shellfish Growing Areas. (Printed as Part I of Public Health Service Publication No. 33.)

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FOREWORD

A Declaration of Principles

The National Shellfish Sanitation Program is an unusual teaming of State and Federal resources to preserve and manage a natural resource for a beneficial use. Although the current program is of comparatively recent origin, its development can be traced back through several centuries of American history. When the European colonists arrived they found almost unimagined natural wealth. Forests, rich agricultural land, minerals, and space itself, were present in quantities and a variety previously unknown. To these settlers one of the most valuable and readily useable of these natural resources was the food resources of the sea, particularly the estuaries. It is not surprising that shellfish were foremost among their staple food items.

The value of these renewable natural resources to the early settlers was reflected in colonial legislation designed to encourage their wise use. In 1658—over 300 years ago—the Dutch council of New Amsterdam passed an ordinance regulating the taking of oysters from the East River. Other early legislation, including that of New York (1715), New Jersey (1730), and Rhode Island (1734), was designed to regulate harvesting, presumably as conservative measures to guarantee a continuing supply.

The public health problems which were associated with shellfish in the United States in the first two decades of the present century brought a new dimension to natural resource utilization; i.e., shellfish could not be used for food unless of acceptable sanitary quality. This concept was clearly recognized in the Public Health Service sponsored conference of 1925 in which the concepts of the present cooperative program were first outlined and the administrative foundation put down. All parties seemed to recognize, and accept as fact, the premises that: (1) shellfish represented a valuable natural food resource; (2) the cultivation, harvesting, and marketing of this food resource were valuable components in the financial bases of many coastal communities; (3) a State and Federal program was necessary to permit the safe use of this resource; and (4) the transmission of disease by shellfish was preventable and therefore not to be tolerated. It is significant that the founders of this program did not take the parochial stand that the only completely safe way to prevent disease transmission by shellfish was to prohibit its use. Instead, they held that this beneficial use of the estuaries was in the best public interest, and that sanitary controls should be developed and maintained which would allow safe use. These concepts were recognized in the program which evolved following the report of the "Committee on Sanitary Control of the Shellfish Industry in the United States" in 1925.

In 1954 the Surgeon General of the U.S. Public Health Service called a second national conference to discuss shellfish sanitation problems. Specifically, the 1954 conference addressed itself to the questions of the practicality and need for this tripartite program. There was general agreement that, despite the profusion of technical problems, the basic concepts were sound and that it was in the public interest to maintain the program. Thus, the presence of an irrevocable bond between the application of sanitary controls in the shellfish industry and the continuing beneficial use of a renewable natural resource was again confirmed.

Despite this long established relationship the national program has tended to neglect the second of these biphasic goals—use of a valuable natural resource—and to concentrate on the negative policy of closure of areas of unsuitable sanitary quality. Little effort has been made by the program to develop a compensatory element which would encourage corrective action by State or Federal agencies. Similarly, the program has not taken a position on the use of conservation law even when it was known that this would increase the program's consumer protection confidence factor.

In recognition of past history of the shellfish industry in the United States and of the relationship of the National Shellfish Sanitation Program to the effective use of this natural resource, the 1964 Shellfish Sanitation Workshop endorses the following principles:

1. Shellfish are a renewable, manageable natural resource of significant economical value to many coastal communities, and which should be managed as carefully as are other natural resources such as forests, water, and agricultural lands.
2. Shellfish culture and harvesting represents a beneficial use of water in the estuaries. This use should be recognized by State and Federal agencies in planning and carrying out pollution prevention and abatement programs and in comprehensive planning for the use of these areas.
3. The goals of the National Shellfish Sanitation Program are: (1) the continued safe use of this natural resource and (2) active encouragement of water quality programs which will preserve all possible coastal areas for this beneficial use.

It is the conviction of the 1964 National Shellfish Sanitation Workshop that survival of the shellfish industry is in the best public interest; that by application of the above principles on a State-by-State basis shellfish can continue to be used safely as food and to make a valuable contribution to the economic structure of the Nation both in the immediate present and in the foreseeable future.

Introduction

In 1925 State and local health authorities and representatives of the shellfish industry requested the Public Health Service to exercise supervision over the sanitary quality of shellfish shipped in interstate commerce. In accordance with this request, a cooperative control procedure was developed. In carrying out this cooperative control, the States, the shellfish industry, and the Public Health Service, each accept responsibility for certain procedures as follows.

1. Procedures To Be Followed by the State.—Each shellfish-shipping State adopts adequate laws and regulations for sanitary control of the shellfish industry, makes sanitary and bacteriological surveys of growing areas, delineates and patrols restricted areas, inspects shellfish plants, and conducts such additional inspections, laboratory investigations, and control measures as may be necessary to insure that the shellfish reaching the consumer have been grown, harvested, and processed in a sanitary manner. The State annually issues numbered certificates to shellfish dealers who comply with the agreed-upon sanitary standards, and forwards copies of the interstate certificates to the Public Health Service.

2. Procedures To Be Followed by the Public Health Service.—The Public Health Service makes an annual review of each State's control program including the inspection of a representative number of shellfish-processing plants. On the basis of the information thus obtained, the Public Health Service either endorses or withholds endorsement of the respective State control programs. For the information of health authorities and others concerned, the Public Health Service publishes a semimonthly list of all valid interstate shellfish-shipper certificates issued by the State shellfish-control authorities.

3. Procedures To Be Followed by the Industry.—The shellfish industry cooperates by obtaining shellfish from safe sources, by providing plants which meet the agreed-upon sanitary standards, by maintaining sanitary plant conditions, by placing the proper certificate number on each package of shellfish, and by keeping and making available to the control authorities records which show the origin and disposition of all shellfish.

The fundamental components of this National Shellfish Sanitation Program were first described in a *Supplement to Public Health Reports*, "Report of Committee on Sanitary Control of the Shellfish Industry in the United States" (1925). This guide for sanitary control of the shellfish industry was revised and reissued in 1937 and again in 1946. It was separated into two parts by publication of Part II, Sanitation of the Harvesting and Processing of Shellfish in 1957 and by publication in 1959, of Part I, Sanitation of Shellfish Growing Areas. The need for a specialized program of this nature was reaffirmed at the National Conference on Shellfish Sanitation held in Washington, D.C., in 1954 (*1*) and at the Shellfish Sanitation Workshop held in 1956 (*2*), 1958 (*3*), 1961 (*67*) and 1964 (*68*).

This edition of the shellfish sanitation manual has been prepared in cooperation with the State shellfish control authorities in all coastal States, food control authorities in the inland States, interested Federal agencies, Canadian Federal departments, the Oyster Institute of North America, the Pacific Coast Oyster Growers Association, and the Oyster Growers and Dealers Association of North America.

Since the growing and processing of shellfish are two distinct phases of operation in the shellfish industry, the manual has been prepared in two parts: I: Sanitation of Shellfish-Growing Areas; and II: Sanitation of the Harvesting and Processing of Shellfish. This, Part I of the manual, is intended as a guide for the preparation of State shellfish sanitation laws and regulations, and for sanitary control of the growing, relaying, and purification of shellfish. It is intended that States participating in the National Shellfish Sanitation program for the certification of interstate shellfish shippers will be guided by this manual in exercising sanitary supervision over shellfish growing, relaying, and purification, and in the issuing of certificates to shellfish shippers.

The manual will also be used by the Public Health Service in evaluating State shellfish sanitation programs to determine if the programs qualify for endorsement. Part III of the manual, "Public Health Service Appraisal of State Shellfish Sanitation Programs", sets forth appraisal procedures in evaluating State shellfish sanitation programs and is based on the requirements contained in parts I and II.

The provisions of this manual were accepted at the Shellfish Sanitation Workshop held in Washington, November 17–19, 1964, and unless otherwise stated become effective 60 days after publication (*68*).

EUGENE T. JENSEN,

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Definitions

And/or.—Where this term is used, *and* shall apply where possible; otherwise, *or* shall apply.

Area, growing.—An area in which market shellfish are grown.

Coliform group.—The coliform group includes all of the aerobic and facultative anaerobic, Gram-negtative, non-spore-forming bacilli which ferment lactose with gas formation within 48 hours at 35° C. Bacteria of this group which will produce gas from E. C. medium within 24 hours at 44.5° C. in a water bath will be referred to as fecal coliforms.

Controlled purification.—The process of removing contamination from whole live shellfish acquired while growing in polluted areas.

National shellfish sanitation program.—The cooperative State-PHS-Industry program for the certification of interstate shellfish shippers as described in Public Health Service Publication Number 33, *National Shellfish Sanitation Program Manual of Operations*, Parts I and II.

Depletion.—The removal of all market-size shellfish from an area.

Most probable number (abbreviated MPN).—The MPN is a statistical estimate of the number of bacteria per unit volume, and is determined from the number of positive results in a series of fermentation tubes. A complete discussion of MPN determinations and computations, including MPN tables, can be found in the American Public Health Association publication "Standard Methods for the Examination of Water and Waste Water" (*4*) (*5*).

Population equivalent (coliform).—A quantity of sewage containing approximately 160×10^9 coliform group bacteria. This is approximately equal to the per capita per day contribution of coliforms as determined in a metropolitan sewerage system (*6*) (*7*) (*8*).

Sanitary survey.—The sanitary survey is the evaluation of all factors having a bearing on the sanitary quality of a shellfish growing area including sources of pollution, the effects of wind, tides, and currents in the distribution and dilution of the polluting materials, and the bacteriological quality of the water.

Shellfish.—All edible species of oysters, clams, or mussels, either shucked or in the shell, fresh or frozen.

Shellfish, market.—Shellfish which are, may be, or have been harvested and/or prepared for sale for human consumption as a fresh or frozen product.

State shellfish control agency.—The State agency or agencies having legal authority to classify shellfish growing areas and/or to issue permits for the interstate shipment of shellfish in accord with the provisions of this manual.

State shellfish patrol agency.—The State agency having responsibility for the patrol of shellfish growing areas.

Transplanting.—The moving of shellfish from one area to another area.

Section A

GENERAL ADMINISTRATIVE PROCEDURES

1. State Laws and Regulations.—State laws or regulations shall provide an adequate legal basis for sanitary control of all interstate phases of the shellfish industry. This legal authority shall enable one or more departments or agencies of the State to classify all coastal waters for shellfish harvesting on the basis of sanitary quality; effectively regulate the harvesting of shellfish; effectively prosecute persons apprehended harvesting shellfish from restricted, prohibited, or nonapproved areas; regulate and supervise the shipment and storage of shell stock, and the shucking, packing, and repacking of shellfish; make laboratory examinations of shellfish; seize, condemn, or embargo shellfish; and restrict the harvesting of shellfish from particular areas and suspend interstate shipper certificates in public-health emergencies.

Satisfactory compliance.—This item will be satisfied when the State has legal authority to—

a. Classify all actual or potential shellfish growing areas as to their suitability for shellfish harvesting on the basis of sanitary quality as defined in section C of this manual. (It is strongly recommended that a State permit be required for the growing of shellfish, and that such permits be revocable or subject to suspension for just cause. It is also recommended that the State have authority to regulate the discharge of sewage, radioactive, and other toxic wastes from boats in the vicinity of approved shellfish growing areas.)

b. Control the harvesting of shellfish from areas which are contaminated or which contain marine shellfish poisons. To be effective this authority must allow the State to—

(1) Patrol growing areas.

(2) Apprehend persons violating the restrictions.

(3) Effectively prosecute persons apprehended harvesting shellfish from *restricted* or *prohibited* areas. (Penalties for such violations should be sufficient to discourage illegal harvesting.)

c. Regulate and supervise relaying, depletion, wet storage, and controlled purification as described in this manual if these techniques are used.

d. Require that shell stock in storage or in transit from the growing area to the certified shipper be protected against contamination; i.e., every person, firm, or corporation that handles shellfish up to the certified shipper will be subject to sanitary control by an official agency but will not necessarily be required to have a State shellfish permit.

e. Prohibit national program shippers from possessing or selling shellfish from out-of-State sources unless such shellfish have been produced in accord with cooperative program requirements.

f. Regulate the operations of shucker-packers, repackers, shell stock shippers and reshippers in accord with the applicable provisions of part II of this manual.

g. Restrict the harvesting of shellfish from specific areas, and suspend interstate shipper certificates in a public-health emergency. **Administrative procedures required in connection with such emergency actions should not require more than one day to complete.**

h. Prevent the sale, shipment, or possession of shellfish which cannot be identified as having been produced in accord with national program requirements or which are otherwise unfit for human consumption, and to condemn, seize, or embargo such shellfish. This authority need not be specific for shellfish and may be included in other State food laws.

Public-health explanation.—The National Program was developed by the 1925 Conference on Shellfish Pollution to meet the specific public-health need resulting from the 1924–25 typhoid epidemic (*9*).

However, the National Program has gone beyond the original objective of insuring that shellfish shipped interstate would not be the cause of communicable disease. Thus, in the 1940's, paralytic shellfish poison became a matter of public-health concern and steps were taken to protect the public against this hazard. In 1957 it was recognized that shellfish might concentrate certain radionuclides and that a radiation surveillance activity might become a necessary adjunct to the established procedures.

To accomplish these public-health objectives the State must supervise all phases of the growing, harvesting, transportation, shucking-packing, and repacking of shellfish to be shipped interstate. It is also important that shellfish be properly refrigerated and protected against contamination during interstate shipment. This is not easily accomplished by the State of origin although certified shippers are required to pack shellfish in containers which will protect them against contamination.

If State supervision is to be effective all phases of the activity must be supported by legal authority. This authority may be either a specific law or regulation. The success with which the State is able to regulate the several components of the shellfish industry provides a measure of the adequacy of the statutory authority.

The unique nature of shellfish as a food also makes it necessary that the State shellfish control agency have authority to take immediate emergency action to halt harvesting or processing of shellfish without recourse to lengthy administrative procedures. As examples, a State may find it necessary to close a shellfish growing area within hours of a breakdown in a sewage treatment plant or the unexpected finding of paralytic shellfish poison.

Periodic revisions of State shellfish laws or regulations may be necessary to cope with new public-health hazards and to reflect new knowledge. Examples of changes or developments which have called for revision of State laws include the wide-scale use of pleasure boats with the resulting probability of contamination of shellfish growing areas with fresh fecal material, the conditionally approved area concept resulting from the construction of sewage treatment works, and the apparent ability of shellfish to concentrate certain radionuclides.

Experience has demonstrated that all actual and potential shellfish growing waters of the State must be classified as to their sanitary suitability for shellfish harvesting. Harvesting should be permitted only from those areas which have been found by sanitary survey to meet the sanitary criteria of this manual. Harvesting should accordingly be specifically prohibited from areas which do not meet the criteria, or which have not been surveyed.

2. General Administrative Procedures To Be Used by States.—States shall keep records which will facilitate Public Health Service review of their shellfish sanitation programs and shall assist the Service in making such reviews. States shall not certify shippers for interstate shipment unless the shipper complies substantially with the construction requirements of part II of this manual and maintains a sanitation rating of at least 80 percent during periods of operation. Shippers not meeting these requirements will not be eligible for inclusion on the Public Health Service list of State-certified shellfish shippers. National Program standards shall be applied to all actual and potential growing areas, all shellfish harvesters, and all persons handling shell stock prior to its delivery to the national program certified shipper. When two or more State agencies are involved in the sanitary control of the shellfish industry, a clear statement of responsibility of each agency should be developed.

Satisfactory compliance.—This item will be satisfied when—

a. National Program requirements are applied to all actual and potential shellfish growing areas.

b. National Program requirements are applied to all commercial market shellfish harvesters.

c. National Program requirements are applied to all persons handling the shellfish prior to its delivery to the interstate shipper.

d. Interstate shellfish shipper certificates are issued only to those establishments substantially meeting the construction requirements of part II of this manual and which maintain a plant sanitation rating of at least 80 percent during periods of operations. (The State shellfish control agency shall suspend or revoke certificates if a plant sanitation rating drops below 80 percent or if any individual sanitation item is violated repeatedly.) Ratings will be determined on the basis of compliance withe the apapplicable provisions of part II of this manual as measured by an inspection report comparable to that contained in appendix A of part II.

e. The following records are kept of shellfish sanitation activities as required in sections C, D, and E, Part I, of this manual and when monthly summaries of State patrol activities are forwarded to the Public Health Service regional office:

(1) Individual growing area files. (Areas may be defined by either geographic or political boundaries.)

(2) Patrol activities, including arrests, prosecutions, and the results of prosecutions.

(3) Plant inspections. Shucker-packers and repackers shall ordinarily be inspected at least monthly. Shell stock shippers and reshippers, shall be inspected at a frequency which will afford adequate public-health supervision of their operations. A central inspection-report file should be maintained by the State.

f. The following guidelines are observed by the State in issuing interstate shellfish certificates.

(1) Certificate content. Each certificate should give the following information:

Name. (The usual business name and alternative names that should appear on the interstate shellfish shippers list, hereafter called "list.")

Address. (A business and/or mailing address in the State issuing the certificate. This address indicates where records are kept and where inspection may be arranged.)

Certificate Number. (A number shall be assigned for each business unit. Suffix or prefix letters may not be used to differentiate between two or more plants of a given shipper.)

Classification. (The shipper classification should be indicated by a symbol: i.e., shucker-packer, SP; repacker, RP; shell stock, SS; or reshipper, RS. Only one classification should be used. The single classification will cover all proposed operations which the shipper is qualified to perform.)

Expiration Date. (All certificates in a State should expire on the same date, preferably the last day of a month. This date will be shown on the "list". All certificates will be automatically withdrawn from the "list" on the date of expiration unless new certificates have been received by Public Health Service headquarters office. If the date of expiration coincides with the date of issue for the "list" the certificates expiring on the date of issue will be deleted.)

Certifying Officer. (Each certificate is signed by a responsible State official.)

(2) Certificate changes. A change in an existing, unexpired certificate should be made by issuing a corrected certificate.

(3) Interstate shipment before listing. The shipper should be informed of the probable date his name will appear on the "list" and should be advised against making interstate shipment prior to that date. (If shipments must be made before the appearance of the shipper's name on the "list", the Public Health Service will notify the applicable receiving States if the names and addresses of the expected receivers are indicated in advance by the State when the certificate is forwarded to the Public Health Service.)

(4) State cancellation, revocation, or suspension of interstate shipper certificates. If a State revokes, cancels, or suspends an interstate shellfish shipper certificate, the Public Health Service regional office should be immediately notified, preferably by telephone or telegram, with a following confirmatory letter.

(5) Mailing list for interstate shellfish shipper list. Names of persons, business units, organizations, or agencies, desiring copies of the "list", and requests for information concerning the "list" should be sent to the appropriate Public Health Service regional office. Recipients will be circularized periodically to determine if they still have use for the "list".

g. The appropriate Public Health Service regional office is notified by the State of any revision in growing area classification. The notification shall so describe the area that it may be readily located on Coast and Geodetic Survey charts.

h. State shellfish plant inspectors are provided with the following inspection equipment: standardized inspection forms, thermometer, chlorine test kit, and light meter.

i. Interdepartmental memoranda of understanding have been developed which will define the responsibilities of each State agency in maintaining adequate sanitary control of the shellfish industry in the State.

Public-health explanation.—The annual review of each participating State's shellfish sanitation activities is a fundamental Public Health Service responsibility in the National Program. The purpose of this review is to evaluate the adequacy and reliability of each individual State program in accord with the agreed-upon standards. The Service will endorse those State programs meeting the National Program standards and will publish and distribute a list of the names of the State certified shippers. However, if a State program does not meet the standards the program will not be endorsed. Names of nonparticipating States will be omitted from the Public Health Service list of State certified shellfish shippers.

Minimum plant sanitation standards for interstate shellfish shippers are described in part II of this manual. Experience has shown that absolute compliance with these minimum standards is not always attainable, particularly those items which relate to operating procedures. The establishment of the 80-percent plant sanitation score as a prerequisite for listing on the Public Health Service list of State certified shellfish shippers recognizes the fact that perfection is not always obtainable and, at the same time, provides a mechanism for excluding any plant which is not operated in a reasonably sanitary manner.

National program sanitary requirements should be applied to all actual and potential growing areas and all shellfish harvesters to insure that all shellfish available to certified dealers have been produced and harvested under acceptable sanitary conditions. It is also important that the shell stock be protected against contamination during the period between harvesting and delivery to the certified shipper.

3. Intrastate Sale of Market Shellfish.—Sanitary standards for intrastate shellfish shippers should be substantially equivalent to those of the national program.

Public-health explanation.—States may accept lower sanitary standards for shellfish sold intrastate than are required by the National Program. However, it has been found that small intrastate shippers may at times sell their product to interstate shippers if demand exceeds the supply of shellfish available to the latter. Because of the possibility that such substandard shellfish might be shipped interstate, the 1954 National Conference on Shellfish Sanitation recommended that National Program standards be applied to all shellfish production and processing (*1*). The 1958 Shellfish Sanitation Workshop also strongly recommended the use of substantially equivalent standards for intra- and inter-state shellfish shippers (*3*).

Section B

LABORATORY PROCEDURES

1. Bacteriological.—American Public Health Association Recommended Procedures for the Examination of Sea Water and Shellfish shall be followed in the collection and transportation of samples of shellfish and shellfish waters for bacteriological examination and in the laboratory examination of such samples.[1]

Satisfactory compliance.—This item will be satisfied when current American Public Health Association Recommended Procedures for the Examination of Sea Water and Shellfish are followed in the bacteriological examination of shellfish and shellfish waters.

Public-health explanation.—Experience with the bacteriological examination of shellfish and shellfish growing waters has indicated that minor differences in laboratory procedures or techniques will cause wide variations in the results. Variations in results may also be caused by improper handling of the sample during collection or transportation to the laboratory (*10*). The American Public Health Association Recommended Procedures for the Examination of Sea Water and Shellfish, which are revised periodically, offer a reliable way of minimizing these variations (*62*). (National Program required use of a standard procedure for the bacteriological examination of shellfish and shellfish waters should not discourage laboratories from working on new methods of sample handling or analysis.)

2. Toxicological.—A recognized procedure shall be used in the assay for paralytic shellfish poison.

Satisfactory compliance.—This item will be satisfied when current Association of Official Agricultural Chemists official methods are followed in the bioassay for paralytic shellfish poison.

Public-health explanation.—It has been demonstrated that significant variations in bioassay results will be caused by minor changes in procedures. If reliable results are to be obtained it is essential that the test procedures be standardized and that variations due to use of strains of mice be minimized (*11*). The official procedure for the bioassay for paralytic shellfish poison adopted by the Association of Official Agricultural Chemists minimizes these variations (*66*). A method of analysis for ciguatera poison in shellfish has been developed (*12*).

3. Chemical and Physical.—Standard laboratory methods shall be used for all salinity, radionuclide, and other chemical and physical determinations made on shellfish or shellfish waters in conjunction with National Program activities. Results shall be reported in standard units.

Satisfactory compliance.—This item will be satisfied when—

a. Chemical and physical measurements on shellfish and shellfish waters are made in accord with accepted laboratory techniques.

b. Results of all chemical and physical determinations are expressed in standard units. (For example, salinity should be expressed in parts per thousand rather than hydrometer readings.)

Public-health explanation.—Standardized laboratory procedures are most apt to produce results in which the State shellfish control agency can have confidence, and facilitate comparative evaluation of data. The need for adherence to standardized procedures should not discourage laboratories from experimental use of nonstandard methods.

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[1] Material which may be useful in interpretation of results of bacteriological examination of shellfish is contained in appendix A.

Section C

GROWING AREA SURVEY AND CLASSIFICATION

1. Sanitary Surveys of Growing Areas.—A sanitary survey shall be made of each growing area prior to its approval by the State as a source of market shellfish or of shellfish to be used in a controlled purification or relaying operation. The sanitary quality of each area shall be reappraised at least biennially and, if necessary, a resurvey made. Ordinarily, resurveys will be much less comprehensive than the original survey since it will only be necessary to bring the original information up to date. Records of all original surveys and resurveys of growing areas shall be maintained by the State shellfish control agency, and shall be made available to Public Health Service review officers upon request.

Satisfactory compliance.—This item will be satisfied when—

a. A sanitary survey has been made of each growing area in the State prior to initial approval of interstate shipments of shellfish from that area. A comprehensive sanitary survey shall include an evaluation of all sources of actual or potential pollution on the estuary and its tributaries, and the distance of such sources from the growing areas; effectiveness and reliability of sewage treatment works; the presence of industrial wastes, pesticides, or radionuclides which would cause a public-health hazard to the consumer of the shellfish; and the effect of wind, stream flow, and tidal currents in distributing polluting materials over the growing area.[2] The thoroughness with which each element must be investigated varies greatly and will be determined by the specific conditions in each growing area.

b. The factors influencing the sanitary quality of each approved shellfish growing area are reappraised at least biennially.[3] A complete resurvey should be made of each growing area in an approved category at least once every ten years; however, data from original surveys can be used when it is clear that such information is still valid.

c. A file which contains all pertinent sanitary survey information, including the dates and results of preceding sanitary surveys is maintained by the State shellfish control agency for each classified shellfish area.

d. The State agency having primary responsibility for this element of the national program develops a system for identification of growing areas.

Public-health explanation.—The positive relationship between sewage pollution of shellfish growing areas and enteric disease has been demonstrated many times (*13*) (*14*) (*15*) (*16*) (*17*) (*18*) (*63*) (*64*) (*65*). However, epidemiological investigations of shellfish-caused disease outbreaks have never established a direct numerical correlation between the bacteriological quality of water and the degree of hazard to health. Investigations made from 1914 to 1925 by the States and the Public Health Service—a period when disease outbreaks attributable to shellfish were more prevalent—indicated that typhoid fever or other enteric disease would not ordinarily be attributed to shellfish harvested from water in which not more than 50 percent of the 1 cc. portions of water examined were positive for coliforms,[4] *provided the areas were not subject to direct contamination with small amounts of fresh sewage which would not ordinarily be revealed by the bacteriological examination.*

Following the oyster-borne typhoid outbreak during the winter of 1924–25 in the United States (*19*) the national shellfish certification program was initiated by the States, the Public Health Service, and the shellfish industry (*9*). Water quality criteria were then stated as:

a. The area is sufficiently removed from major sources of pollution so that the shellfish would not be subjected to fecal contamination in quantities which might be dangerous to the public health.

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[2] In making the sanitary survey consideration should be given to the hydrographic and geographic characteristics of the estuary, the bacteriological quality of the growing area water and bottom sediments, and the presence and location of small sources of pollution, including boats, which might contribute fresh sewage to the area.

[3] The purpose of this reappraisal is to determine if there have been changes in stream flow, sewage treatment, populations, or other similar factors which might result in a change in the sanitary quality of the growing area. The amount of field work associated with such a reappraisal will depend upon the area under consideration and the magnitude of the changes which have taken place.

[4] An MPN of approximately 70 per 100 ml.

Section C

GROWING AREA SURVEY AND CLASSIFICATION

1. Sanitary Surveys of Growing Areas.—A sanitary survey shall be made of each growing area prior to its approval by the State as a source of market shellfish or of shellfish to be used in a controlled purification or relaying operation. The sanitary quality of each area shall be reappraised at least biennially and, if necessary, a resurvey made. Ordinarily, resurveys will be much less comprehensive than the original survey since it will only be necessary to bring the original information up to date. Records of all original surveys and resurveys of growing areas shall be maintained by the State shellfish control agency, and shall be made available to Public Health Service review officers upon request.

Satisfactory compliance.—This item will be satisfied when—

a. A sanitary survey has been made of each growing area in the State prior to initial approval of interstate shipments of shellfish from that area. A comprehensive sanitary survey shall include an evaluation of all sources of actual or potential pollution on the estuary and its tributaries, and the distance of such sources from the growing areas; effectiveness and reliability of sewage treatment works; the presence of industrial wastes, pesticides, or radionuclides which would cause a public-health hazard to the consumer of the shellfish; and the effect of wind, stream flow, and tidal currents in distributing polluting materials over the growing area.[2] The thoroughness with which each element must be investigated varies greatly and will be determined by the specific conditions in each growing area.

b. The factors influencing the sanitary quality of each approved shellfish growing area are reappraised at least biennially.[3] A complete resurvey should be made of each growing area in an approved category at least once every ten years; however, data from original surveys can be used when it is clear that such information is still valid.

c. A file which contains all pertinent sanitary survey information, including the dates and results of preceding sanitary surveys is maintained by the State shellfish control agency for each classified shellfish area.

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Public-health explanation.—The positive relationship between sewage pollution of shellfish growing areas and enteric disease has been demonstrated many times (*13*) (*14*) (*15*) (*16*) (*17*) (*18*) (*63*) (*64*) (*65*). However, epidemiological investigations of shellfish-caused disease outbreaks have never established a direct numerical correlation between the bacteriological quality of water and the degree of hazard to health. Investigations made from 1914 to 1925 by the States and the Public Health Service—a period when disease outbreaks attributable to shellfish were more prevalent—indicated that typhoid fever or other enteric disease would not ordinarily be attributed to shellfish harvested from water in which not more than 50 percent of the 1 cc. portions of water examined were positive for coliforms,[4] *provided the areas were not subject to direct contamination with small amounts of fresh sewage which would not ordinarily be revealed by the bacteriological examination.*

Following the oyster-borne typhoid outbreak during the winter of 1924-25 in the United States (*19*) the national shellfish certification program was initiated by the States, the Public Health Service, and the shellfish industry (*9*). Water quality criteria were then stated as:

a. The area is sufficiently removed from major sources of pollution so that the shellfish would not be subjected to fecal contamination in quantities which might be dangerous to the public health.

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[2] In making the sanitary survey consideration should be given to the hydrographic and geographic characteristics of the estuary, the bacteriological quality of the growing area water and bottom sediments, and the presence and location of small sources of pollution, including boats, which might contribute fresh sewage to the area.

[3] The purpose of this reappraisal is to determine if there have been changes in stream flow, sewage treatment, populations, or other similar factors which might result in a change in the sanitary quality of the growing area. The amount of field work associated with such a reappraisal will depend upon the area under consideration and the magnitude of the changes which have taken place.

[4] An MPN of approximately 70 per 100 ml.

b. The area is free from pollution by even small quantities of fresh sewage. The report emphasized that bacteriological examination does not, in itself, offer conclusive proof of the sanitary quality of an area.

c. Bacteriological examination does not ordinarily show the presence of the coli-aerogenes group of bacteria in 1 cc. dilutions of growing area water.

The reliability of this three-part standard for evaluating the safety of shellfish-producing areas is evidenced by the fact that no major outbreaks of typhoid fever or other enteric disease have been attributed to shellfish harvested from waters meeting the criteria since they were adopted in the United States in 1925. Similar water quality criteria have been in use in Canada with like results. The available epidemiological and laboratory evidence gives little idea as to the margin of safety, but it is probably considerable as indicated by the virtual absence of reported shellfish caused enteric disease over a comparatively long period of time *(18)* *(20)* *(21)* *(65)* *(69)* from waters meeting this criteria.

The purpose of the sanitary survey is to identify and evaluate those factors influencing the sanitary quality of a growing area and which may include sources of pollution, potential or actual; the volume of dilution water; the effects of currents, winds and tides in disseminating pollution over the growing areas; the bacterial quality of water and bottom sediments; die out of polluting bacteria in the tributaries and the estuary; bottom configuration; and salinity and turbidity of the water. Sources of pollution include municipal sewage discharged into the estuary or inflowing rivers; sewage brought into the estuary by tides or currents; surface runoff from polluted areas; industrial wastes; and discharges from pleasure craft, fishing boats, naval vessels, and merchant shipping.

Bacteriological examination of the growing waters is an important component of the sanitary survey. In many instances the bacteriological and related salinity data will also provide valuable information on the hydrographic characteristics of an area.[5] [6]

Ideally, a large number of water samples for bacteriological examination should be collected at each station. However, in most instances this is not practical because of time and budget limitations, and accordingly only a limited number of samples can be collected. Therefore, sampling stations should be chosen which will provide a maximum of data, and which will be respresentative of the bacteriological quality of water in as wide an area as possible. Sample collection should be timed to represent the most unfavorable hydrographic and pollution conditions since shellfish respond rapidly to an increase in the number of bacteria or viruses in their environment *(25)* *(26)* *(70)* *(71)* *(72)* *(78)*.

There is no specified minimum number of sampling stations, frequency of sampling, or total number of samples. Sampling results obtained over a period of several years can be used as a block of data provided at least 15 samples have been collected from each of a representative number of stations along the line separating approved from restricted growing areas and there have been no adverse changes in hydrographic or sanitary conditions. Only occasional bacteriological samples are necessary from areas which are shown to be free from pollution.

Experience with the shellfish certification program indicates a tendency to omit or de-emphasize some components of the sanitary survey unless a central State file of all shellfish sanitary surveys, reappraisals, and resurveys is maintained. This is particularly true where responsibility for shellfish sanitation is divided between two or more State agencies. Maintenance of a central State file for all shellfish sanitary survey information will also simplify the endorsement appraisal of State programs by the Public Health Service and will help prevent loss of old data which may be useful in evaluating the sanitary quality of an area.

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[5] Bacteria in an unfavorable environment die out in such a way that following an initial lag period there is a large percentage decline during the first few days. Descriptions of studies on bacteria dieout have been published by Greenberg *(22)* and Pearson *(23)*. Dieoff has also been investigated by the Public Health Service Shellfish Sanitation Laboratory at Woods Hole, Mass., and Pensacola, Fla. Application of this principle may be helpful in predicting the quantity of pollution which will reach an area, and in establishing objective effluent quality criteria *(24)*.

[6] In connection with the evaluation of sampling results, it should be noted that the MPN determination is not a precise measure of the concentration of bacteria *(4)*. Thus, in repeated sampling from waters having a uniform density of bacteria varying MPN estimates will be obtained. The use of the tolerance factor 3.3 (applicable only to 5 tube decimal dilution MPN's) is one method of recognizing this variation. For example, in a body of water in which the median concentration of coliform bacteria is 70 per 100 ml., 95% of observed MPN's will be between 20 and 230 per 100 ml.; i.e., 70/3.3=21 and 70×3.3=230.

Periodic reappraisals of the sanitary quality of shellfish producing areas are necessary to determine that environmental conditions are such that the original conclusions are still valid. A *resurvey* should be made within 1 year if the *reappraisal* shows a significant detrimental change.

2. Classification of Growing Areas.—All actual and potential growing waters shall be classified as to their public health suitability for the harvesting of market shellfish. Classification criteria are described in sections C–3, C–4, C–5, C–6, and C–7 of this manual. Except in emergency any upward revision of an area classification shall be preceded by a sanitary survey, resurvey, or reappraisal. A written analysis of the data justifying the reclassification shall be made a part of the area file.

Satisfactory compliance.—This item will be satisfied when—

a. All actual and potential growing waters in the State are correctly designated with one of the following classifications on the basis of sanitary survey information: *Approved; conditionally approved; restricted;* or *prohibited.*[7] *

b. Area classifications are revised whenever warranted by survey data.

c. Classifications are not revised upward without at least a file review, and there is a written record of such review in the area file maintained by the State shellfish control agency.

d. All actual and potential growing areas which have not been subjected to sanitary surveys shall be automatically classified as *prohibited.*

Public-health explanation.—The probable presence or absence of pathogenic organisms in shellfish waters is of the greatest importance in deciding how shellfish obtained from an area may be used. All actual and potential growing waters should thus be classified according to the information developed in the sanitary survey. Classification should not be revised upward without careful consideration of available data. Areas should be reclassified whenever warranted by existing data. A written justification for the reclassification simplifies Public Health Service appraisal of State programs.

A hypothetical use of the four recognized area classifications is shown in figure 1. This idealized situation depicts an estuary receiving sewage from two cities, "A" and "B." City "A" has complete sewage treatment including chlorination of effluent. City "B" has no sewage treatment. The estuary has been divided into five areas, designated by roman numerals, on the basis of sanitary survey information:

Approved

Area I. The sanitary survey indicates that sewage from cities "A" and "B" (even with the "A" sewage plant not functioning) would not reach this area in such concentration as to constitute a public-health hazard. The median coliform MPN of the water is less than 70/100 ml. The sanitary quality of the area is independent of sewage treatment at city "A."

Conditionally Approved

Area II. This area is of the same sanitary quality as area I; however, the quality varies with the effectiveness of sewage treatment at city "A." This area would probably be classified *prohibited* if city "A" had not provided sewage treatment.

Restricted

Area III. Sewage from "B" reaches this area, and the median coliform MPN of water is between 70 and 700 per 100 ml. Shellfish may be used only under specified conditions .

Prohibited

Area IV. Direct harvesting from this area is prohibited because of raw sewage from "B." The median coliform MPN of water may exceed 700/100 ml.

Area V. Direct harvesting from this area is prohibited because of possible failure of the sewage treatment plant. Closure is based on need for a safety factor rather than coliform content of water or amount of dilution water.

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[7] Closures may also be based on presence of Marine Toxins or other toxic materials.

*States may use other terminology in describing area classifications; provided, that the classification terms used are consistent with the intent and meaning of the words "approved", "conditionally approved", "restricted", or "prohibited".

3. Approved Areas.—Growing areas may be designated as *approved* when: (*a*) the sanitary survey indicates that pathogenic microorganisms, radionuclides, and/or harmful industrial wastes do not reach the area in dangerous concentration, and (*b*) this is verified by laboratory findings whenever the sanitary survey indicates the need. Shellfish may be taken from such areas for direct marketing.

Satisfactory compliance.—This item will be satisfied when the three following criteria are met:

a. The area is not so contaminated with fecal material that consumption of the shellfish might be hazardous, and

b. The area is not so contaminated with radionuclides or industrial wastes that consumption of the shellfish might be hazardous (see section C, item 7, regarding toxins in shellfish growing areas), and

c. The coliform median MPN of the water does not exceed 70 per 100 ml., and not more than 10 percent of the samples ordinarily exceed an MPN of 230 per 100 ml. for a 5-tube decimal dilution test (or 330 per 100 ml., where the 3-tube decimal dilution test is used) in those portions of the area most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions. (Note: This concentration might be exceeded if less than 8 million cubic feet of a coliform-free dilution water are available for each population equivalent (*coliform*) of sewage reaching the area). The foregoing limits need not be applied if it can be shown by detailed study that the coliforms are not of direct fecal origin and do not indicate a public health hazard (*19*) (*20*).[8]

Public-health explanation.—A review of epidemiological investigations of disease outbreaks attributable to the consumption of raw shellfish reveals that two general situations prevail[9] insofar as pollution of growing or storage areas are concerned.

(1) Gross sewage contamination of a growing or wet storage area. (A report of a 1910 outbreak of typhoid fever involving 41 persons notes that raw sewage from a city with a population of 30,000 was discharged only a few hundred feet away from clam beds and floats (*27*) (*28*). In 1947 a case of typhoid fever was attributed to clams harvested 200 yards from the outlet of a municipal sewage treatment plant (*29*). In the latter case, the coliform MPN of the harbor water exceeded 12,000 per 100 ml. and the area had been posted as closed to shellfish harvesting.)

(2) Chance contamination of a growing or wet storage area by fresh fecal material which may not be diffused throughout the entire area (*14*) (*16*) (*17*) (*19*) and therefore not readily detectable by ordinary bacteriological procedures. The possibility of chance contamination was noted by Dr. Gurion in his report on a 1902 typhoid outbreak, and who is quoted in Public Health Bulletin No. 86, as "there is a zone of pollution established by the mere fact of the existence of a populated city upon the banks of a stream or tidal estuary which makes the laying down of oysters and clams in these waters a pernicious custom if persisted in, because it renders these articles of food dangerous at times, and always suspicious". The 1956 outbreak of infectious hepatitis in Sweden (691 cases) attributed to oysters which were contaminated in a wet storage area is an example of such contamination (*16*). Similarly in 1939, 87 cases of typhoid were attributed to fecal contamination of a storage area by a typhoid carrier (*14*).

It is well established that shellfish from water having a median coliform MPN not exceeding 70 per 100 ml.[8] *and which is also protected against chance contamination with fecal material*, will not be involved in the spread of disease which can be attributed to initial contamination of the shellfish. This is not surprising since a water MPN of 70/100 ml. is equivalent to a dilution ratio of about 8 million cubic feet of coliform-free water per day for the fecal material from each person contributing sewage to the area. This tremendous volume of water is available in shellfish growing areas through

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[8] This MPN value is based on a typical ratio of coliforms to pathogens and would not be applicable to any situation in which an abnormally large number of pathogens might be present. Consideration must also be given to the possible presence of industrial or agricultural wastes in which there is an atypical coliform to pathogen ratio (*30*).

[9] There is a third general consideration in which shellfish may be contaminated through mishandling. This is not related to growing area sanitation and is considered in part II of this manual.

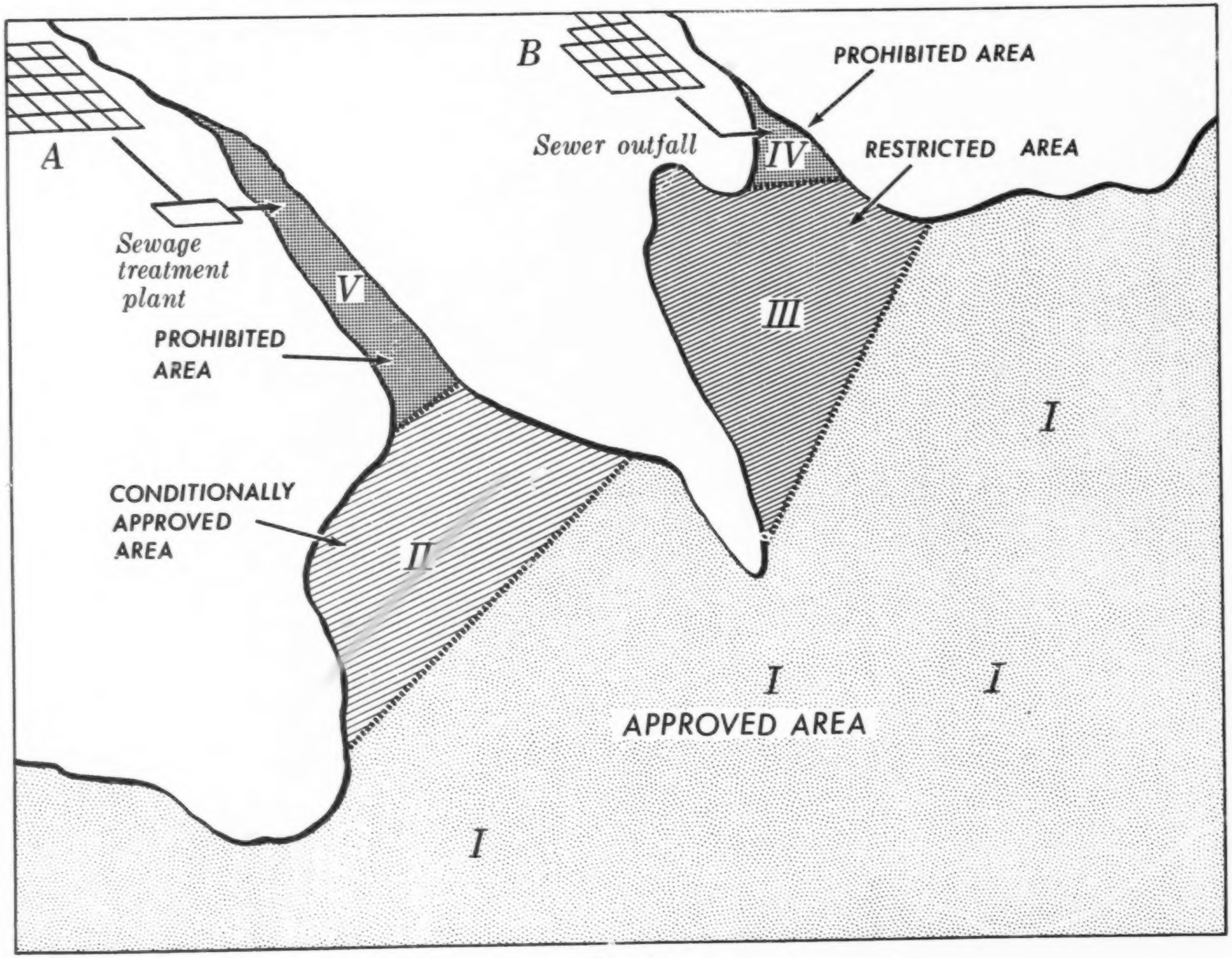
A
B
Sewage treatment plant
Sewer outfall
PROHIBITED AREA
RESTRICTED AREA
V
IV
III
PROHIBITED AREA
CONDITIONALLY APPROVED AREA
II
I
I
I
I
APPROVED AREA

FIGURE 1

tidal action which is constantly bringing unpolluted water into the area.[8]

Areas which are approved for direct market harvesting of shellfish which will be eaten raw must necessarily meet one general test; i.e, sewage reaching the growing area must be so treated, diluted, or aged that it will be of negligible public-health significance. This implies an element of time and distance to permit the mixing of the sewage or fecal material with the very large volume of diluting water and for a major portion of the microorganisms to die out. Studies of the natural die-off of microorganisms in an unfavorable marine environment have been summarized by Greenberg (*22*).

The effectiveness of sewage treatment processes must be considered in evaluating the sanitary quality of a growing area since the bacterial and viral content of the effluent will be determined by the degree of treatment which is obtained (*2*) (*73*) (*74*) (*75*). The results of bacteriological sampling must also be correlated with sewage treatment plant operation, and evaluated in terms of the minimum treatment which can be expected with a realization of the possibility of malfunctioning, overloading, or poor operation.

The presence of radionuclides in growing area waters may also have public-health significance since shellfish, along with other marine organisms, have the ability to concentrate such materials (*31*) (*32*) (*33*) (*34*). The degree to which radioisotopes will be concentrated depends upon the species of shellfish and the specific radioisotope. For example, it has been reported that the Eastern oyster has a concentration factor of 17,000 for Zn^{65} whereas the concentration factor in soft tissues for Sr^{89} is approximately unity (*31*) (*33*). The distribution of the radioisotope in the shellfish and the biological half-life are also variable. Sources of radioactive materials include fall-out, industrial wastes, and nuclear reactors. Limiting maximum permissible concentrations of radioactive materials expressed in terms of specific radioisotopes and unidentified mixtures in water and food have been established (*35*) (*36*). The current standard should be consulted in evaluating the public-health significance of detected radioactivity in market shellfish.

The bacterial quality of active shellfish will ordinarily be directly proportional to the bacterial quality of the water in which they grew; however, considerable variation in individual determinations may be expected. The coliform MPN's of the shellfish usually exceed those of the overlying water because shellfish filter large quantities of water to obtain food, thereby concentrating the suspended bacteria. This relationship will depend upon the shellfish species, water temperature, presence of certain chemicals, and varying capabilities of the individual animals.

4. Conditionally Approved Areas.—The suitability of some areas for harvesting shellfish for direct marketing is dependent upon the attainment of an established performance standard by sewage treatment works discharging effluent, directly or indirectly, to the area. In other cases the sanitary quality of an area may be effected by seasonal population, or sporadic use of a dock or harbor facility. Such areas may be classified as *conditionally approved*.

State shellfish control agencies shall establish *conditionally approved* areas only when satisfied that (a) all necessary measures have been taken to insure that performance standards will be met, and (b) that precautions have been taken to assure that shellfish will not be marketed from the areas subsequent to any failure to meet the performance standards and before the shellfish can purify themselves of polluting microorganisms.

Satisfactory compliance.—This item will be satisfied when—

a. The water quality requirements for an *approved* area are met at all times while the area is approved as a source of shellfish for direct marketing.

b. An operating procedure for *each conditionally approved* area is developed jointly by the State shellfish control agency, local agencies, including those responsible for operation of sewerage systems, and the local shellfish industry. The operating procedure should be based on an evaluation of each of the potential sources of pollution which may affect the area. The procedure should establish performance standards, specify necessary safety devices and measures, and define inspection and check procedures. (These procedures are described in

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See footnote 8 on page 13.

more detail in the following public-health explanation.)

c. A closed safety zone is established between the *conditionally approved* area and the source of pollution to give the State agency time to stop shellfish harvesting if performance standards are not met.

d. Boundaries of *conditionally approved* areas are so marked as to be readily identified by harvesters.

e. Critical sewerage system units are so designed, constructed, and maintained that the chances of failure to meet the established performance standards due to mechanical failure or overloading are minimized.

f. There is a complete understanding of the purpose of the *conditionally approved* classification by all parties concerned, including the shellfish industry. Successful functioning of the concept is dependent upon the wholehearted cooperation of all interested parties. If such cooperation is not assured the State should not approve the area for direct harvesting of market shellfish.

g. Any failure to meet the performance standards is immediately reported to the State shellfish control agency by telephone or messenger. In some instances States may find it desirable to delegate the authority for closing a *conditionally approved* area to a representative of the agency located in the immediate area.

h. The State immediately closes *conditionally approved* areas to shellfish harvesting following a report that the performance standards have not been met. The area shall remain closed until the performance standards can again be met plus a length of time sufficient for the shellfish to purify themselves so that they will not be a hazard to the public health. (See section D-1, "Relaying," for information on the length of time required for self-purification of shellfish.)

i. The State shellfish control agency makes at least two evaluations during the shellfish harvesting season of each *conditionally approved* area including inspection of each critical unit of the sewerage system to determine the general mechanical condition of the equipment, the accuracy of recording devices, and the accuracy of reporting by the operating agency.

j. It is discovered that failure to meet performance standards have not been reported by the operating agency, or if the performance standards are not met, the area will immediately revert to a *restricted* or *prohibited* classification.

k. All data relating to the operation of a *conditionally approved* area, including operation of sewerage systems, are maintained in a file by the State shellfish control agency.

Public-health explanation.—The *conditionally approved* classification is designed primarily to protect shellfish growing areas in which the water quality might undergo a significant adverse change within a short period of time.[10] The change might result from overloading or mechanical failure of a sewage treatment plant, or bypassing of sewage at a lift station.

Water quality in many growing areas in the more densely populated sections of the country is, to some degree, dependent upon the operation of sewage treatment plants. For example, the boundaries of an approved shellfish area might be determined during a period when a tributary sewage treatment plant is operating at a satisfactory level. If there is some interruption in treatment it follows that there will be some degradation in water quality in the growing area, which may justify a relocation of the boundaries. The degree of relocation would depend upon such items as the distance between the pollution source and the growing area, hydrography, the amount of dilution water, and the amount of pollution.

The concept is also applicable to other situations in which there may be a rapid or seasonal change in water quality. Examples of such situations include—

a. A growing area adjacent to a resort community. During the summer months the community might have a large population which might have an adverse effect on water quality. However, during the winter when there are few people in the community the water quality might improve sufficiently to allow approval of the area. In some States this is known as a seasonal closure.

b. A protected harbor in a sparsely settled area might provide anchorage for a fishing fleet several months a year. When the fishing fleet is in, the harbor water would be of poor sanitary quality; however, during the remainder of the year the quality of the harbor water might be satisfactory. The area would be approved for shellfish harvesting only when the fishing fleet is not using the harbor.

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[10] A natural disaster may also cause many sewage treatment plants to be out of service for an extended period of time. The *conditionally approved* area concept is not ordinarily concerned with such emergency situations.

c. The water quality in an area fluctuates with the discharge of a major river. During periods of high runoff the area is polluted because of decreased flow time in the river. However, during periods of low runoff the area might be of satisfactory quality and thus be approved for shellfish harvesting.

The establishment of *conditionally approved* areas might be considered whenever the potential for sewage contamination is such that the limiting water quality criteria for an *approved* area might be exceeded in less than one week due to a failure of sewage treatment, or other situations as described above.

The first step in determining whether an area should be placed in the *conditionally approved* classification is the evaluation of the potential sources of pollution in terms of their effect on water quality in the area. Potential sources of pollution include the following:

(1) Sewage treatment plants.
  (*a*) Bypassing of all or part of sewage because of mechanical or power failure, hydraulic overloading, or treatment overloading.
  (*b*) Reduced degree of treatment due to operational difficulties or inadequate plant.
(2) Sewage lift stations.
  (*a*) Bypassing during periods of maximum flow due to inadequate capacity.
  (*b*) Bypassing because of mechanical or power failure.
(3) Interceptor sewers or underwater outfalls.
  (*a*) Exfiltration due to faulty construction.
  (*b*) Leakage due to damage.
(4) Other sources of pollution.
  (*a*) Sewage from merchant or naval vessels.
  (*b*) Sewage from recreation use of area.

The second step in establishment of a *conditionally approved* area is the evaluation of each source of pollution in terms of the water quality standards to be maintained, and the formulation of performance standards for each installation having a significant effect on the sanitary quality of the area. Examples of performance standards might include:

(1) Bacteriological quality of effluent from sewage treatment plants. This might be stated in terms of chlorine residual if the bacteriological quality of the effluent can be positively related to chlorine residual. The following is an example of a performance standard (*37*): "The median coliform MPN, in any one month, shall not exceed 500 per 100 ml., based on not less than 16 composite samples per month, and not more than 10 percent of the samples shall have an MPN in excess of 10,000 per 100 ml. Determinations of the chlorine residual of the effluent should be made hourly and recorded in the permanent plant records."

(2) Total quantity of sewage which can be discharged from any given unit, or from a combination of units, without causing the basic water quality standards to be exceeded.

(3) Amount of shipping in the area and the amount of sewage which can be expected.

Design criteria which may be useful in formulating an opinion on the quantity of sewage which can be discharged into an area without exceeding the desired water quality standards include: Population equivalent (*coliform*) of sewage; predicted survival of coliform in sea water, effectiveness of chlorination, and the total quantity of clean dilution water in an area. Results of many studies on the survival of bacteria in sea water have been summarized in *An Investigation of the Efficacy of Submarine Outfall Disposal of Sewage and Sludge;* Publication No. 14, California State Water Pollution Control Board, 1956.

The mechanical equipment at critical sewage treatment or pumping units should be such that interruptions will be minimized. Wherever possible operations should be automatically recorded on charts. Examples of the requirements which might be imposed, depending upon the importance of the unit in terms of water quality, include:

(1) Ample capacity for storm flows. (Storm water should ordinarily be excluded from the sanitary system.)

(2) Standby equipment to insure that treatment or pumping will not be interrupted because of damage to a single unit or to power failure.

(3) Instrumentation of pumps and equipment to allow the regulatory agency to determine that performance standards have been met. Examples include:

(*a*) Recording scales to indicate rate of chlorine use. Chlorine flow can be integrated with hydraulic flow to establish a ratio.

(*b*) Liquid level recording gages in overflow channels of sewage treatment plants and wet wells of lift stations to indicate when overflow takes place. Charts should be dated and initialed by the operator. Gages should be calibrated so that discharge can be estimated.

(*c*) Automatic devices to warn of failure or malfunctioning at self-operated pumping stations or treatment plants.

(4) The effect of storm sewage can be calculated by multiplying the total estimated flow by the observed coliform content. The result can be expressed in terms of population equivalents (*coliform*).

Design and operation of equipment should be such that closure provisions should not have to be invoked more than once per year under ordinary circumstances.

A closed safety area should be interposed between the *conditionally approved* area and the source of pollution. The size of such area should be based on the total time it would take for the operating agency to detect a failure, notify the State shellfish control agency, and for the latter agency to stop shellfish harvesting. It is recommended that the area be of such size that the flow time through the safety area be at least twice that required for the notification process to become effective. Due consideration should be given to the possibility that closure actions might be necessary on holidays or at night.

The type of marking which will be required for *conditionally approved* areas will vary from State to State depending upon the legal requirements for closing an area.

The length of time a *conditionally approved* area should be closed following a temporary closure will depend upon several factors including the species of shellfish, water temperature, purification rates, presence of silt or other chemicals that might interfere with the physiological activity of the shellfish, and the degree of pollution of the area. (See section D–1 of this manual for additional information on the natural purification of shellfish.)

5. Restricted Areas.—An area may be classified as *restricted* when a sanitary survey indicates a limited degree of pollution which would make it unsafe to harvest the shellfish for direct marketing. Alternatively the States may classify such areas as prohibited. (See section C–6, this manual.) Shellfish from such areas may be marketed after purifying or relaying as provided for in section D.

Satisfactory compliance.—This item will be satisfied when the following water quality criteria are met in areas designated by States as *restricted*.[11] [12]

a. The area is so contaminated with fecal materials that direct consumption of the shellfish might be hazardous, and/or

b. The area is not so contaminated with radionuclides or industrial wastes that consumption of the shellfish might be hazardous, and/or

c. The coliform median MPN of the water does not exceed 700 per 100 ml. and not more than 10 percent of the samples exceed an MPN of 2,300 per 100 ml. in those portions of the areas most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions. (Note: this concentration might be exceeded if less than 800,000 cubic feet of a coliform-free dilution water are available for each population equivalent (*coliform*) of sewage reaching the area.)

d. Shellfish from *restricted* areas are not marketed without controlled purification or relaying.

Public-health explanation.—In many instances it is difficult to draw a clear line of demarcation between polluted and nonpolluted areas. In such instances the State may, at its option, classify areas of intermediate sanitary quality as *restricted* and authorize the use of the shellfish for relaying, or controlled purification.

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[11] It is not mandatory that States use this classification. Areas not meeting the *approved* classification may be closed to all harvesting for direct marketing.

[12] Routine sanitary surveys and reappraisals of *restricted* areas shall be made on the same frequency as for *approved* areas. (See section C–1.)

6. Prohibited Areas.—An area shall be classified *prohibited* if the sanitary survey indicates that dangerous numbers of pathogenic microorganisms might reach an area. The taking of shellfish from such areas for direct marketing shall be prohibited. Relaying or other salvage operations shall be carefully supervised to insure against polluted shellfish entering trade channels. Actual and potential growing areas which have not been subjected to sanitary surveys shall be automatically classified as *prohibited.*

Satisfactory compliance.—This item will be satisfied when:

a. An area is classified as *prohibited* if a sanitary survey indicates either of the following degrees of pollution:

(1) The area is contaminated with radionuclides or industrial wastes that consumption of the shellfish might be hazardous and/or

(2) The median coliform MPN of the water exceeds 700 per 100 ml. or more than 10 percent of the samples have a coliform MPN in excess of 2,300 per 100 ml. (Note: This concentration might be reached if less than 800,000 cubic feet of a coliform-free dilution water are available for each population equivalent (*coliform*) of sewage reaching the area.)

b. No market shellfish are taken from *prohibited* areas except by special permit as described in section D.

c. Coastal areas in which sanitary surveys have not been made shall be automatically classified as *prohibited.*

Public-health explanation.—The positive relationship between enteric disease and the eating of raw or partially cooked shellfish has been outlined in section C-1. Prevention of the interstate transport of shellfish containing sufficient numbers of pathogenic microorganisms to cause disease is a primary objective of the National Program. Therefore, areas containing dangerous concentrations of microorganisms of fecal origin, or areas which may be slightly contaminated with fresh fecal discharges, should not be approved as a source of shellfish for direct marketing.

7. Closure of Areas Due to Shellfish Toxins.—The State shellfish control agency shall regularly collect and assay representative samples of shellfish from growing areas where shellfish toxins are likely to occur. If the paralytic shellfish poison content reaches 80 micrograms per 100 grams of the edible portions of raw shellfish meat, the area shall be closed to the taking of the species of shellfish in which the poison has been found.[10] The harvesting of shellfish from such areas shall be controlled in accord with the recommendations of sections E-1 and E-2 of this manual.

The quarantine shall remain in effect until such time as the State shellfish control agency is convinced the poison content of the shellfish involved is below the quarantine level.[11]

Satisfactory compliance.—This item will be satisfied when—

a. The State shellfish control agency collects and assays representative samples of shellfish for the presence of toxins from each suspected growing area during the harvesting season. (See section B-2 for assay methods.)

b. A quarantine is imposed against the taking of shellfish when the concentration of paralytic shellfish poison equals or exceeds 80 micrograms per 100 grams of the edible portion of raw shellfish.

Public-health explanation.—In some areas paralytic poison is collected temporarily by bivalve shellfish from free-swimming, one-celled marine plants on which these shellfish feed. The plants flourish seasonally when water conditions are favorable.

Cases of paralytic poisoning, including several fatalities, resulting from poisonous shellfish have been reported from both the Atlantic and Pacific coasts. The minimum quantity of poison which will cause intoxication in a susceptible person is not known. Epidemiological investigations of paralytic shellfish poisoning in Canada have indicated 200 to 600 micrograms of poison will produce symptoms in susceptible persons and a death has been attributed to the ingestion of a probable 480 micrograms of poison. Investigations indicate that lesser amounts of the poison have no deleterious effects on humans. Growing areas should be closed at a lower toxicity level to provide an adequate margin of safety since in many instances toxicity levels will change rapidly (*38*) (*39*). It has also been shown that the heat treatment afforded in ordinary canning processes reduces the poison content of raw shellfish considerably.

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[10] This value is based on the results of epidemiological investigations of outbreaks of paralytic shellfish poison in Canada in 1954 and 1957 (38) (39).

[11] The provisions of this item apply only to shellfish which will be marketed as a fresh or frozen product as properly controlled heat processing will reduce the poison content of the shellfish.

A review of literature and research dealing with the source of the poison, the occurrence and distribution of poisonous shellfish, physiology and toxicology, characteristics of the poison, and prevention and control of poisoning has been prepared (*40*).

In Gulf coast areas, toxicity in shellfish has been associated (*12*) (*76*) with Red Tide outbreaks caused by mass bloomings of the toxic dinoflagellate, *Gymnodinium breve*. Toxic symptons in mice suggest a type of *ciguatera* fish poisoning rather than symptoms of paralytic shellfish poisoning.

Section D

PREPARATION OF SHELLFISH FOR MARKETING

1. Relaying.—State shellfish control agencies may approve the intra- or interstate transplanting of market shellfish from restricted or prohibited areas to approved areas subject to certain limitations. All phases of the operation shall be under the immediate supervision of responsible State(s) shellfish control or patrol agency(s). A memorandum of understanding shall be developed between the agencies responsible for the control of interstate relaying operations. (Shellfish may be transplanted from an *approved* area to another like area at any time without restriction due to sanitary reasons.)

Satisfactory compliance.—This item will be satisfied when—

a. Shellfish are not relaid from *restricted* or *prohibited areas* to *approved areas* without written permission of the State shellfish control agency.

b. All relaying operations are under the *immediate* supervision of the State shellfish control or patrol agency. Supervision shall be such that no polluted shellfish are marketed before the end of the approved relaying period. The supervising officer shall be authorized and equipped to enforce the State regulations on relaying: shall actually supervise the harvesting, transport and relaying of shellfish; and shall patrol the *approved* area during the period that shellfish are undergoing the cleansing process. However, continuous supervision will not be necessary if relaying operations are carried out during a period when shellfish may not be marketed. A continuous record of water temperature, salinity, and any other critical variables must be maintained when it is known that the limiting values may be approached and when the minimum relaying periods are being used.

c. State permission to relay shellfish is given only to responsible persons; responsibility to be determined by the past record of the permit applicant.

d. Relaid shellfish are held in the *approved* area for a period of time sufficient to allow them to cleanse themselves of polluting bacteria. (The time required for purification will be determined by water temperature, salinity, initial bacteriological quality and species of shellfish.)

e. Relaid shellfish are not harvested without written permission from the State shellfish control agency.

f. Areas designated for relaid shellfish are so located and marked that they may be readily identified by the harvesters and so that shellfish in any adjacent *approved* area will not be contaminated. (This requirement applies only to relaying during the harvesting season.)

g. Shellfish are not relayed intra or interstate from restricted or prohibited areas to *approved* areas without written permission of the State(s) shellfish control agency(s). (If shellfish are relayed interstate, a memorandum of agreement shall be developed outlining the control measures to be used.)

Public-health explanation.—Shellfish transplanted from a polluted to a clean environment will cleanse themselves of the polluting bacteria or viruses. This is a natural phenomenon resulting from the shellfish feeding processes. Bacteria or viruses in the body and shell cavity of the shellfish at the time of transplanting are either used as food or are ejected in feces or pseudofeces.

The length of time required for this cleansing process is influenced by many factors including original level of pollution, water temperature, presence of chemicals inhibitory to physiological activity of the shellfish, salinity, and varying capabilities of the individual animals. Advice on limiting water temperatures, either maxmum or minimum, should be obtained from local marine biologists.

Investigations by marine biologists have confirmed that the psysiological activities of the Eastern oyster (*Crassostrea virginica*) is reduced when the water temperature falls below a certain value. It has been found that the pumping rate of Eastern oysters is reduced at water temperatures below 50° F., and that most animals stop pumping at a water temperature of about 41° F. However, a few oysters show slight activity at temperatures approaching 32° F. (*41*)(*42*). This phenomenon was first noted by shellfish bacteriologists who found that Eastern oysters harvested from polluted areas during cold weather had coliform contents comparable with those of oysters harvested from clean areas during warmer weather (*43*) (*44*) (*45*).

Gibbard *et al.* (*46*) investigating temperature-induced hibernation was unable to demonstrate coliforms in Eastern oysters within a few days after the water temperatures dropped to 32° F. The rapidity with which hibernating oysters become active when the water temperature rises above the threshold value was discussed by Wachter (*47*) in 1925 and was demonstrated by Gibbard *et al.* (*46*). The latter investigator found that contamination accompanying a sudden two degree increase in water temperature from 41° to 43° F. was reflected in the oysters in one day.

Relaying operations must be carefully supervised by an official State agency since the shellfish may contain pathogenic microorganisms. Control must apply to all phases of the operation including initial harvesting, transportation, replanting, purification period, and final harvesting for marketing if the relaying area is adjacent to a restricted area or to an area containing relaid shellfish which have not been released for harvesting.

2. Controlled Purification.—Shellfish from *restricted* or *prohibited* areas may be marketed after effective controlled purification. Purification shall be permitted only under the immediate supervision of the State shellfish control agency. Water used for purification shall be of high bacteriological quality and its physical and chemical properties shall be favorable to maximum physiological activity of the shellfish. Stringent precautions shall be taken by the State shellfish control agency to insure that shellfish harvested from *restricted* or *prohibited* areas are actually submitted to an effective purification process before marketing.

Purification of shellfish from *prohibited* areas shall not be approved by the State unless relaying is not practical for biological reasons, and no public-health hazard will result from the use of such shellfish.

Satisfactory compliance.—This item will be satisfied when:

a. The controlled purification system, including water treatment, has been demonstrated to be consistently effective for the species of shellfish being purified. Purification may be accomplished in either a natural body of water or in tanks. (In determining the effectiveness of the process at least the following factors shall be investigated: Water temperature, silt or turbidity, dissolved oxygen, presence of chemicals, and time required for purification.) The bacteriological quality of the purified shellfish shall be at least equal to shellfish of the same species harvested from local *approved* areas.

b. A purification plant operating procedure is developed and copies are supplied to the Public Health Service.

c. Water used for purification is obtained from an area meeting the physical and bacteriological requirements of an *approved* growing area, or in the case of treated water the bacteriological limits of the Public Health Service Drinking Water Standards (*48*) are met. If water is to be treated, it shall be obtained from an area meeting at least the sanitary requirements for a *restricted* area.

d. Water used for purification has chemical and physical characteristics conducive to maximum physiological activity of the shellfish. (Consideration shall be given to the following: Presence of chemicals, turbidity, temperature, salinity and dissolved oxygen, and to the adequacy of the facilities of the operating agency for measuring these characteristics.)

e. Shellfish are freed of contamination and foreign material adhering to shells before purification.

f. Shellfish are culled before and after purification.

g. Purification plant operation is under the administrative control of the State shellfish control agency. Purification plants may be operated by agencies other than the State; however, insofar as the National Shellfish Sanitation Program is concerned, the State is responsible for satisfactory operation.

h. Laboratory control is maintained over the purification operation. Controls shall include at least the following: Daily or tidal-cycle bacteriological quality of water; final bacteriological quality for each lot of shellfish purified; and, when they are critical factors, hourly or continuous salinity determinations and tidal-cycle turbidity determinations.

i. The plant operator possesses a satisfactory knowledge of the principles of water treatment and bacteriology.

j. Animals, rodents, and unauthorized persons are excluded from the plant.

k. Plant employees fulfill the qualifications for a shucker as described in section B-28, part II of this manual.

l. The State has an effective system for assuring that shellfish harvested from *restricted* areas will be submitted to purification before marketing. Shellfish harvesting from *prohibited* areas for controlled purification shall be under the immediate supervision of the State.

m. Shellfish from *prohibited* areas are not subjected to purification unless the State shellfish control agency can show that relaying or depletion is not biologically feasible; and that no public-health hazard will result from the use of such shellfish.

Public-health explanation.—The ability of shellfish to purify themselves in clean water was discovered early in the 1900's. The biological process is reasonably well understood and is described by Arcisz and Kelly (*26*) as follows:

"Purification is a mechanical process effected by the physiological functioning of the shellfish in clean water. When shellfish are feeding, the gills act as a filter to strain out some of the material that may be brought in by the water which passes through them. If this water contains sewage, some of the microorganisms in it are entrapped in the mucus on the body of the shellfish and transferred to the alimentary tract. Some of these are perhaps utilized as food (*49*) and the others discharged from the body in the form of feces and pseudofeces. When shellfish from polluted water are placed in clean water, the sewage bacteria are eliminated from the shellfish, and, since no more are ingested, purification is accomplished."

The purification process has been investigated extensively in England and to a lesser extent in the United States and Canada (*50*) (*51*) (*52*). The technique is reliable if proper methods are used, and insofar as is known, is applicable to all commercial species of shellfish.

Many of the earlier investigators suggested that purification be accomplished in tanks using water which had been subjected to a treatment process (*52*). The analogy with water treatment was carried to the point of recommending a chlorine residual in the purification tanks. However, fishery biologists have shown that shellfish pumping is decreased or inhibited by even small quantities of chlorine (*53*) (*54*). The inhibitory effect of chlorinated-dechlorinated water on activity of Eastern oysters has been noted by the Public Health Service Shellfish Sanitation Laboratory.

Since purification depends upon the pumping rate of the shellfish, it is important that the water be free of chemicals or physical characteristics which might interfere with this activity. For example, silt or dissolved organic substances may influence the pumping rates of shellfish (*55*) (*56*). The relationship of water temperature to pumping rates has been mentioned previously.

Shellfish purification facilities have generally been considered to include holding tanks and water treatment facilities (*57*) (*58*); however, investigations in Canada and England have demonstrated that purification can be accomplished with relatively simple installations if the operation is supervised properly (*59*) (*50*) (*60*) (*61*). Accordingly, any purification process of *proven* effectiveness will be accepted by the national program.

Administrative control of the purification process is necessary to insure that shellfish are properly washed and culled, are held for the required length of time, and that the purification water supply is properly controlled.

Section E

CONTROL OF HARVESTING FROM CLOSED AREAS

1. Identification of Closed Areas.—Shellfish harvesters shall be notified by direct notice and warning signs of areas closed to harvesting. Closed areas shall be so marked or described that they may be easily recognized by the harvesters. The measures necessary to accomplish delineation and notification will vary with the structure of the local shellfish industry and with the legal requirements of each State.

Satisfactory compliance.—This item will be satisfied when:

a. The boundaries of the closed areas are marked by fixed objects or landmarks in a manner which permits successful prosecution of any violations of the closed areas.

b. Shellfish harvesters are notified of the location of closed areas by publication or direct notification (such as registered mail) and/or warning signs posted at points of access to each closed area. The method of notification and identification should permit the successful prosecution of persons harvesting shellfish from the closed areas. (The limiting of shellfish harvesting permits to specific areas is an alternative to posting or notification. Where such a system is used, posting will be required only for closed areas which contain market shellfish.)

Public-health explanation.—Previous sections of this manual have described the public-health reasons for limiting shellfish harvesting to areas free of contamination and shellfish toxins. Methods have been described for the evaluation and classification of such areas. However, classification is not effective unless the State can prevent illegal harvesting of shellfish for direct marketing from these closed areas.

For the most part, control of illegal harvesting depends upon the police activities as described in section E-2. However, adequate delineation of the closed areas is fundamental to effective patrol.

The type of area identification will be determined by the structure of the local shellfish industry. Posting a warning sign is one method of informing shellfish harvesters that an area is closed to the taking of shellfish for public-health reasons. However, if the local shellfish industry is highly organized, with shellfish being harvested by only a few operators, identification may be accomplished by officially informing the harvesters that certain areas are closed to the taking of shellfish. It is recommended that the advice of the State's legal counsel be obtained to insure that the marking of closed areas and notifications to shellfish harvesters are such that illegal harvesting can be prosecuted successfully.

2. Prevention of Illegal Harvesting of Shellfish From Closed Areas.—Closed growing areas shall be patrolled by a State agency to prevent illegal harvesting. The patrol force shall be so equipped that its officers will be able to apprehend persons taking shellfish from closed areas.

Satisfactory compliance.—This item will be satisfied when—

a. There is no evidence that shellfish are being harvested from closed areas except by special permit as required to meet local conditions.

b. Closed shellfish growing areas are patrolled by representatives of an official agency, due consideration being given to night, weekend and holiday patrols. (States may delegate patrol activities to local organizations; however, responsibility for effective control will remain with the State insofar as the National Program is concerned.

c. Patrol forces are so equipped that persons observed in closed areas may be apprehended.

d. Complete records of patrol activities, including violations and court actions, are maintained in the central office of the State shellfish control or patrol agency. It will be the responsibility of the State to include local patrol activities in these records. (See section A, subsection 2(e) regarding monthly summaries of patrol activities.)

Public-health explanation.—The primary objective of the National Program is to insure that shellfish will be harvested only from areas which are free of dangerous concentrations of pathogenic microorganisms, industrial or radioactive wastes, pesticides or shellfish toxins.

Growing areas may be classified as to their public-health suitability for shellfish harvesting on the basis of information obtained by sanitary and toxicological surveys. However, if local shellfish harvesters are not convinced of the need for restrictions, shellfish may be harvested surreptitiously from the closed areas. Thus, patrol failure may nullify the public-health safeguards resulting from sanitary survey activities.

The fact that law prohibits the removal of shellfish from certain areas will deter most persons from attempting to harvest such shellfish provided they are aware of the law and of the areas which are closed. However, local public opinion may not support the need for such closures. In such cases favorable opinion can probably be developed only through an educational program or a locally demonstrated need such as an epidemic or outbreak of paralytic shellfish poisoning. There is also a minority element not concerned with the welfare of their customers and who, through ignorance or purpose, will attempt to circumvent the harvesting restrictions.

Patrols must, therefore, be directed against three classes of individuals; i.e., those who are ignorant of the law, those who believe the law is unjust or unreasonable, and those who have no regard for the law.

Several mechanisms for improving the effectiveness of patrols include educational programs to acquaint shellfish harvesters with the public-health reasons for the closures, elimination of the "temptation element" by depletion, and relaying or purification. Apprehension, prosecution, and punishment of violators is a final resort.

The type of patrol organization needed for any particular situation cannot be specified and is determined by the nature of areas to be patrolled, means of access, methods of harvesting, and species. Patrol equipment should be such that the officers can apprehend persons harvesting shellfish in a closed area. Necessary equipment might include patrol boats capable of operating in open waters; small, high-speed, readily transportable boats, or patrol automobiles. In many instances, two-way radio will be helpful in coordinating patrol activities. Radar surveillance systems might also be of assistance, particularly during foggy weather or at night.

Organization of the patrol activity must take into consideration the need for night, weekend, holiday, and surprise patrols. Either nuisance or continual patrol may be used depending on the nature of the area to be patroiled and the type of industry.

The adequacy of State laws as a basis for prosecution is an important component of this activity. Shellfish patrol will probably be ineffective if State laws are so written or interpreted that violators cannot be successfully prosecuted, or if penalties are so small that they are economically unimportant. The latter point may be important in an area where local public opinion does not support the need for the restriction.

3. Depletion of Closed Areas.—The State shellfish control or patrol agency shall supervise all depletion operations. All market-size shellfish and as many of the smaller size as can be gathered by reasonable methods shall be removed in the initial depletion operation. Depletion of each area shall be carried out at intervals to prevent the development of market-sized shellfish.

Satisfactory compliance.—This item will be satisfied when—

a. The State shellfish control or patrol agency exercises direct supervision over each depletion project including patrol of the area in which the shellfish are relaid. (See section D-1.)

b. All market shellfish and as many of the smaller size shellfish as can be gathered by reasonable methods are removed in the depletion operation.

c. Similar supervised depletion operations are carried out at intervals to prevent development of market-sized shellfish in quantities which would make commercial harvesting economically practicable in the depleted areas.

Public-health explanation.—Complete removal of shellfish from polluted to clean areas under appropriate precautions is the best safeguard against contaminated shellfish reaching the market. In some cases depletion may be more economical and effective than patrol of closed areas.

Appendix A

BACTERIOLOGICAL CRITERIA FOR SHUCKED OYSTERS AT THE WHOLESALE MARKET LEVEL

The development of satisfactory bacteriological criteria for interstate shipments of oysters as received at the wholesale market level has been under consideration since 1950. At that time the Canadian Department of National Health and Welfare pointed out that most of the U.S.-shucked Eastern oysters sold in Canada had high coliform MPN's, high standard plate counts, or both (*2*). The Canadian experience with market standards for oysters was discussed at the 1956 National Shellfish Sanitation Workshop (*2*) and the Workshop adopted on an interim basis the following bacteriological standard for shucked Eastern oysters at the wholesale market level:

"*Class 1, Acceptable:* Shucked oysters with a Most Probable Number (MPN) of coliform bacteria of not more than 16,000 per 100 ml., and/or a Standard Plate Count of not more than 50,000 per ml.

"*Class 2, Acceptable on Condition:* Shucked oysters with a coliform MPN greater than 16,000 per 100 ml., but less than 160,000 per ml., and/or a Standard Plate Count greater than 50,000 per ml., but less than 1 million per ml. (The oysters will be accepted on the condition that the shellfish sanitation authority in the originating State will make immediate investigation of the producer's plant and operations and will submit a report of such investigations to the control agency in the market area. On the basis of this report the control agency in the market will reject or permit further shipments from the producer in question.)

"*Class 3, Rejectable:* Shucked oysters with a coliform MPN of 160,000 or more per 100 ml., and/or a Standard Plate Count of 1 million or more per ml."

In establishing the above interim standards, the 1956 Workshop recognized the limitations of the coliform group as an index of quality in that it failed to reveal whether the shellfish had been harvested from polluted areas or had been exposed to contamination during handling and processing subsequent to removal from the water. A recommendation was made that investigations be conducted to evaluate the significance of other bacterial indices. The fecal coliform group was suggested as a possible substitute for the coliform indices.

In partial fulfillment of this suggestion, a report on an interstate cooperative study to evaluate bacteriological criteria for market oysters was presented at the 1958 Shellfish Sanitation Workshop (*3*). A feature of this report was the development and evaluation of a method for the estimation of fecal coliform organisms following a procedure originally developed by Hajna and Perry (*77*). Gross increases in coliform organisms were observed during normal acceptable commercial practices. The magnitude of changes in coliform organisms was of the same order as those observed in plate counts. The results clearly demonstrated the inadequacy of the coliform group as an indicator of the sanitary quality of shellfish. It was further concluded that the plate count was of equal significance in revealing chance contamination or violations of acceptable storage time and temperature. On the other hand, the results of the examinations for fecal coliform organisms revealed a much higher degree of stability as the shellfish proceeded through commercial channels and thus suggested the greater suitability of this parameter as an index of sanitary quality at the wholesale market level. After due consideration of the report, the 1958 Workshop changed the interim bacteriological standard for fresh and frozen shucked oysters at the wholesale market level to the following:

> *Satisfactory.*[15] *E. coli* density of not more than 78 MPN per 100 ml. of samples as indicated by production of gas in E. C. liquid broth media nor more than 100,000 total bacteria per ml. on agar at 35° C. will be acceptable without question. An *E. coli* content of 79 to 230 MPN per 100 ml. of sample or a total bacteria count of 100,000 to 500,000 per ml. will be acceptable in occasional samples. If these concentrations are found in two successive samples from the same packer or repacker, the State regulatory authority at the source will be requested to supply information to the receiving State concerning the status of operation of this packer or repacker.
>
> *Unsatisfactory.*[15] *E. coli* content of more than 230 MPN per 100 ml. of sample or a total bacteria count of more than 500,000 per ml. will constitute an unsatisfactory sample and may be subject to rejection by the State shellfish regulatory authority. Future shipments to receiving markets by the shipper concerned will depend upon satisfactory operational reports by the shellfish regulatory authorities at the point of origin.
>
> In adopting the above standards, the 1958 Workshop recommended that the cooperative studies conducted by city and State laboratories and the Public Health Service be continued.

The 1961 Workshop reviewed still more data collected by the collaborating agencies during the 1958–61 period (*67*) and after considerable deliberation agreed to continued use of the interim bacteriological standards arrived at by the 1958 Workshop.

The 1964 Workhop considered all bacteriological data available up to that time (Nov. 17–19), including data relative to *Crassostrea gigas*, and adopted the following standards on a permanent basis, versus the previous interim basis, as being applicable to all species of fresh and frozen oysters at the wholesale market level, *provided they can be identified as having been produced under the general sanitary controls of the National Shellfish Sanitation Program.*[16]

Satisfactory. Fecal coliform density[17] of not more than 230 MPN per 100 grams and 35° C. plate count[18] of not more than 500,000 per gram will be acceptable without question.

Conditional. Fecal coliform density of more than 230 MPN per 100 grams and/or 35° C. plate count of more than 500,000 per gram will constitute a conditional sample and may be subject to rejection by the State shellfish regulatory authority. If these concentrations are found in two successive samples from the same shipper, the State regulatory authority at the source will be requested to supply information to the receiving State concerning the status of operation of this shipper. Future shipments to receiving markets by the shipper concerned will depend upon satisfactory operational reports by the shellfish regulatory authorities at the point of origin.

In establishing the above bacteriological standards the 1964 Workshop took cognizance of the fact that no known health hazard was involved in consuming oysters meeting the standard; that oysters produced in the Gulf Coast States with warmer growing waters, could meet the standard if harvested, processed, and distributed according to the National Shellfish Sanitation Program requirements, and that the oysters harvested were from "approved" growing areas complying with the standards for growing areas established in part I of the PHS Publication No. 33.

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[15] *E. coli* was defined as coliforms which will produce gas from E. C. medium within 48 hours at 44.5° C. in a water bath will be referred to as fecal coliforms.

[16] The standards are not considered meaningful in the absence of such information.

[17] Fecal coliform organisms are those which, on transfer to E.C. medium from gas positive presumptive broth tubes show production of gas after incubation in a water bath at 44.5° C. ±0.2° C. for 24 hours. Where air incubation is at 45.5° C. ±0.2° C. comparative tests must be made to determine comparable time of incubation.

[18] Plate count is the number of bacteria determined by the "Standard Plate Count: procedure for shellfish described in the APHA Recommended Procedures for the Bacteriological Examination of Sea Water and Shellfish."

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U.S. GOVERNMENT PRINTING OFFICE: 1965 O—784-95[illegible]

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APPENDIX B

Odor Evaluation Test Procedures and Results

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101–11.6

UNITED STATES GOVERNMENT

Memorandum

FEDERAL WATER QUALITY ADMINISTRATION
5555 Ridge Avenue, Cincinnati, Ohio 45213

TO :

DATE: November 20, 1970

FROM :

SUBJECT:

ODOR EVALUATION REPORT

Product : Oysters and Water from Galveston Bay

Submitted by : John G. Connor, Division of Field Investigations--Denver Center

Dates Tested : November 16 and 17, 1970

Panel : 4 experienced judges; 2 inexperienced judges; 6 judgments per sample

Samples : Controls (Ref.) and samples 1, 2, 3, 4a, 5, 6, 7

Procedure : The live oysters were thoroughly scrubbed, individually wrapped in aluminum foil, and baked at 450° until the shells opened (approximately 45 minutes). One reference oyster and one sample oyster were submitted to each panelist. The judges were asked to score the degree of odor from each sample on a seven point scale--from 7, no odor, to 1, very extreme odor.* The raw oysters were evaluated by placing the meat from three oysters in screw top jars. The judges were given two jars--one containing a reference and the other containing sample oysters. The odor was scored on the same 1 to 7 point scale.

The threshold odor on the water samples was determined by the method prescribed in the 12th edition of "Standard Methods for the Examination of Waters and Waste Waters."

Results : The results from the oyster odor evaluation were analyzed by the Chi-square test. A linear regression was performed on the results from the water and the oyster samples to determine the relationship between the odor of the Galveston Bay water samples and the odor of the oysters.

---

* Score sheet appended.

5010–108

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In the raw oyster test, the reference and sample 1 received similar scores as would be expected in that the reference samples were drawn from sample 1. All the remaining samples scored significantly lower (.05) than the reference sample. Samples from stations 2 and 4a were given the lowest rating (very strong odor). The samples from station 2 were characterized by some of the panelists as having a petroleum odor, while the samples from station 4a had a sewage odor. The samples from stations 3, 5, and 6 had strong odors, while the sample from station 7 received a rating almost the same as that given to the reference and the samples from station 1.

The results from the roasted oyster odor test indicate the same pattern of off-odor. The testing of the roasted oysters was limited to stations 3, 5, 7, and a reference from station 1 because of the extreme odors being emitted from the oyster shells.

The results from the water odor tests indicate that the water from station 1 had the lowest threshold odor. The samples from stations 3 and 4a received the highest threshold odor values. The linear regression between the odor evaluations of the raw oysters and the water samples indicates that there is no correlation between the two. Upon examination of the water odor results, it was found that station 2 received a very low threshold odor value. If the results from station 2 are eliminated, a very high correlation (.9) exists between the odor of the water and the odor of the oysters obtained from the same stations in Galveston Bay. The validity of the water sample from station 2 should be investigated as it might have been influenced by abnormal hydrological conditions.

In conclusion, only the oysters from station 1 did not have a strong off-odor. The strong odor of the oysters from stations 2, 3, and 4a would lower their palatability, thus reducing the marketability of these shellfish.

ODOR EVALUATION DATA

	Sample							
Judge	Ref.	1	2	3	4	5	6	7
				RAW OYSTERS				
1	4.0	5.0	4.0	2.0	4.0	4.0	4.0	5.0
2	4.5	4.5	3.5	1.5	2.0	1.5	2.5	4.0
3	5.0	6.0	4.5	4.5	5.0	4.5	6.0	6.0
4	6.0	6.0	2.0	5.0	2.0	5.0	7.0	4.0
5	4.0	4.0	2.0	4.0	2.0	4.0	2.0	5.0
6	5.0	4.0	2.0	6.0	2.5	5.0	2.5	3.0
Total	28.5	29.5	18.5	23.0	17.5	24.0	24.0	27.0
Average	4.8	4.9	3.1	3.8	2.9	4.0	4.0	4.5
Chi-square		0.65	5.7	3.4	6.3	2.2	3.5	2.2
Probability of the distribution being less than x^2 statistical		0.014	0.67	0.36	0.72	0.18	0.37	0.18
			Petroleum		Sewage			
				ROASTED OYSTERS				
1	6.0	-	-	5.0	-	5.0	-	6.0
2	5.0	-	-	4.0	-	4.0	-	5.0
3	5.0	-	-	5.0	-	3.0	-	5.0
4	4.0	-	-	4.0	-	6.0	-	6.0
5	7.0	-	-	4.0	-	5.0	-	4.0
6	6.0	-	-	1.0	-	4.0	-	6.0
Total	33.0			23.0		27.0		32.0
Average	5.5			3.8		4.5		5.3
Chi-square				5.8		3.4		2.2
Probability of the distribution being less than x^2 statistical				0.67		0.36		0.19
				WATER SAMPLES				
Geometric mean of threshold odor values		5	6	32	32	18	23	11

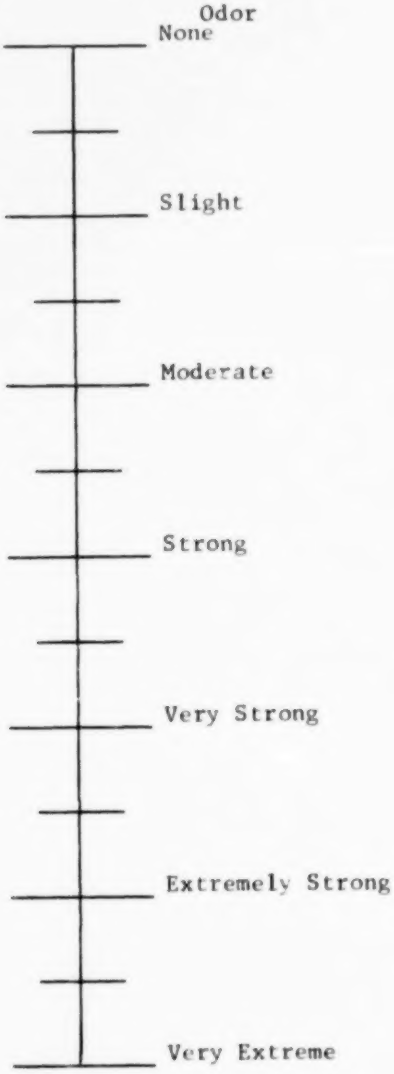
DIVISION OF FIELD INVESTIGATIONS

CINCINNATI

Name______________________________

Date______________________________

Sample____________________________


Odor
None
Slight
Moderate
Strong
Very Strong
Extremely Strong
Very Extreme

Type of Odor____________________________

GPO 835-030